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POPULAR EXPLANATION

OF THE

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ELEMENTS AND GENERAL LAWS

OF

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CHEMISTRY.

BY WALTER WELDON.

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PREFACE.

AN attention to chemistry has of late become very general and popular. It may be considered as a necessary branch of liberal education. It contains stores of useful knowledge that are applicable, and valuable to persons in every station of life.

An extensively detailed knowledge of chemistry cannot be obtained by every one. The science is now [illegible] and extensive in its outline than is [illegible] contemplated. The extent of its objects is apt to be overlooked in the attention to its manipulations, and minuter details. It has rapidly grown up into an extensive accumulation of facts, to which additions are making almost daily, from various quarters, both of Europe, and even of America. It requires such an appropriation of time and property; such a variety of expensive and delicate instruments; such an acquisition of manual dexterity; and so much thought and attention for its successful prosecution, as will necessarily confine the *professed pursuit* of it to a few [illegible] enthusiastic amateurs, who [illegible] tunity favour.

But a general knowledge of the outlines of chemical science may be readily obtained by any one who will take the trouble to obtain it. Where the least desire of knowledge prevails, the time and trouble spent upon it is amply repaid. Neither is it difficult for those occupied in other pursuits, to obtain a sufficiently detailed knowledge of those particular parts or branches of chemistry, that may be useful to their particular sciences, arts, or manufactures.

The advantages attending it need not now be dwelt upon.

Public lectures are of late given upon this branch of science; not merely in semi- of liberal education, but in many of the -al towns of England, and on the Continent, -y render a taste for chemistry popular. The demonstrations and manipulations, at the same time, are better understood by seeing them, than they can be by description. But the numerous details and general laws cannot be understood and retained through all their applications from oral demonstrations only.

Several valuable works on chemistry are extant in English, as well as in foreign languages. There -s some temerity, therefore, in attempt- -g a fresh one. But mankind -y do other branches of

science, with different views. Many, having other professions to pursue, or other avocations to follow, are unable, or unwilling, to spend much time and labour in the acquisition of collateral, and, as they esteem it, ornamental or amusing information merely. The laborious mechanic, to whom a knowledge of the general principles of chemistry would oftentimes be useful, frequently turns with dismay from both the expense, and labour, of three or four volumes; of which he, perhaps, does not duly appreciate the value. The amateur, or the female reader, is frequently dismayed by similar feelings.

It has been thought, therefore, that if an essay were produced upon the elements of chemical science; explaining its general laws and principal phenomena, by including such a detail of facts as is sufficient to exemplify, and explain them, a kind of bird's-eye view, if the phrase may be allowed, of the science in its present state; at the same time using the most explicit and popular terms, avoiding mathematical, and, as far as is possible, complex arithmetical calculations, and controversial points, which are generally too obscure to be interesting to readers unlearned in the science; and reducing the subject within the limits of a moderate volume, it would be favourably received by the public.

This is all that is pretended to in this volume.

The principles and elements of chemistry are the principles and elements of the material world. We obtain our perceptions of them, through the medium of our senses only. It is difficult, therefore, to explain, or even to comprehend, the various phenomena, and curious metamorphoses that are ever presenting themselves to us in this fairy science, without a reference to the equally curious properties of our senses. In the prosecutions of the more obscure investigations, their properties and limits should never be lost sight of. We shall find that bodies must possess many properties not perceptible through the medium of our senses, but that are deducible by our judgments; while the necessary and strictest deductions only are allowable. Other properties of bodies no doubt exist, and other agencies of which our senses give us no information. To us they are as if they had no existence. It is in vain that the most profound philosopher attempts to imagine properties or agencies. Every day's experience shews that the universe was not created according to the imbecile fancy of man. If philosophers, theorists, and physicians had always duly attended to this consideration, a great deal of learned nonsense would have been prevented.

Hypothesis has here been avoided as far as is practicable. But it is not possible to arrange numerous collections of facts so that the recollection can retain them, without some hypothesis to tie

them, as it were, together. Indeed hypothesis is so engrafted in the terms of scientific language, that it is not possible to speak intelligibly, in some branches of science, without the use of terms implying an hypothesis.

The reader, who wishes to obtain further information than this volume affords, will find many parts of chemistry treated more in detail in the writings of Fourcroy, Murray, Davy, Gay-Lussac, Thomson, Brande, and Ure; and in the treatises of Berzelius and M. Thenard, a part of both of which are translated into English, by Mr. Children. These books will furnish further references also.

A

POPULAR EXPLANATION

OF THE

GENERAL LAWS AND ELEMENTS

OF

CHEMISTRY.

DIVISION I.

INTRODUCTORY REMARKS.

THE examination of the elements and agencies constituting the physical world, of the laws and properties that influence it, and of the phenomena they produce, may be called general physical science.

For the convenience of explanation, and of its adaptation to the limited faculties of man, it has been very generally divided into NATURAL HISTORY, PHYSICS, and CHEMISTRY, and these have been subdivided into numerous secondary branches. These divisions, although necessary to the reader as well as to the student, require some latitude. Too strict an adherence to them would very much cramp the attainment of knowledge. He, who in the pursuit of knowledge confines himself to one branch only of science, will obtain a very inadequate and imperfect knowledge of that single branch. There are certainly many things which are peculiar to each branch of knowledge; there are many also which are more general and extend to many; and others that extend to every branch of knowledge; and that cannot well be understood without the consideration of their general influence. Classification appears to be a very secondary

consideration with the Creator of the universe. Between the noblest subject of the creation which the faculties of man enable him to contemplate, and the most insignificant, there are very few distinct divisions. With one or two exceptions, and those perhaps apparent only, the changes among things are full of gradations and analogies.

Between the noblest created being that man is permitted to contemplate,—his own mind—and the Creator, we are sensible of an awful chasm; in which all is to us a blank. There may, however, be various orders of created beings, in extensive gradations rising above man; in the number and extent of their senses, as well as in their intellectual powers, although we have no perception of them, nor conception of their faculties. We observe, or at least we think we observe, a wide chasm on the other side, between the intellect of man generally, and that of the most sagacious brute; but that chasm may be filled up by various races of animated beings, inhabitants of the worlds around us. Vanity has a strong tendency to widen this little interval. The world we inhabit appears to us at an incredible distance from every other, yet astronomy shows us, that it is one of a numerous closely set group, and that it occupies merely a point in the creation.

When the nature of time and of space is contemplated, it is perceived that they must be boundless. By the organ of sight we perceive numerous fixed glittering spots or stars in the distant regions of space; by reasoning, analogy, and such experiments, observations, and comparisons, as astronomy has been able to contrive, it is concluded that they are suns, resembling that which is the centre of our solar system; and that each is probably surrounded by its planetary worlds. If these inferences are just, it is most probable that these worlds are more or less inhabited by animated beings, equally adapted to their respective peculiar stations, as the animals of this globe are to theirs.

In the solar system it is perceived, that the sun, while by its gravitation it supports its planetary worlds in their respective revolutions, is also the source of light and warmth to them. Those planets all so much resemble the earth as to afford a strong presumption that, like it, they are all inhabited worlds.

But no conception can be formed of the nature of their inhabitants, nor of their senses, faculties, nor properties. They may resemble the beings of this world, slightly modified only, to adapt them to the differences and peculiarities of their respective situations. They may altogether differ. It is more than probable that man, constituted as he is, could scarcely exist in any of the planets. In the moon he would probably be lost for want of water, and of an atmosphere: in the planet Mercury, his body would be evaporated into smoke: in the planet Saturn, or in the Herschian star, it would be frozen to a solid. So helpless is man, and so limited the capability of his existence! But, reasoning upon the knowledge we possess, we are led to conclude, that the power, wisdom, and ubiquity of our Creator is boundless, like time and space; and, consequently, that all things are adapted to their particular stations and uses.

Between the intellectual powers of man, and those of the most perfect of the animals around him, the difference, as we have said, is great. In organization or bodily power, or in the relative perfection of the organs of sense, the difference is inconsiderable. In particular animals, certain organs are more perfect even than they are in man. To the eye of the eagle, objects are visible at a distance far greater than they are to the human eye. The olfactory sense in the vulture, or the hound, can discern smells that to man are imperceptible. Every animal has some certain parts or functions in greater perfection than the rest, to adapt it to the peculiar station and way of life it is intended for. There are, at the same time, numerous analogies among

animals, as well as a gradual deviation in the perfection of their structure and powers; extending through the various orders, until we descend to those that, in point of intellect, are the lowest in the scale, and are with difficulty discerned to possess sensations, or distinct organization. Even here the attention and wisdom of the Creator are marked. The helpless and almost senseless polyp has a tenacity of life, and a means of renovation and reproduction, which is denied to more perfect animals.

Thus animation sinks almost imperceptibly into vegetation. The boundary between them was long unknown, and is distinguishable frequently by nice discrimination only. In the vegetable system, similar phenomena appear. Strong analogies of resemblance are attended with gradually varying structure and appearance, through every step of our search.

The difficulties that have attended the investigation of the laws and agencies producing the phenomena around us, have been more numerous than at first is apparent.

Man, stamped by his Creator with certain bodily and mental faculties, and an intuitive de[illegible] of improving his situation, power, and knowledge—[illegible]ions dormant and unknown to himself, until circ[illegible]ces stimulate them into action; appears to have bee[illegible]ed naked and ignorant into the world.

For a long period after his creation, [illegible]ion being thin, the genial climate of Asia, apparently h[illegible]t abode, bountifully supplied his wants from her spo[illegible]us productions. As population increased, these source[illegible]ne insufficient; and the golden age of peaceful ignoran[illegible]nd idle plenty, gradually passed away. Want began t[illegible]ss, and all the faculties were employed in obtaining, by artifice, or force, a precarious subsistence.

The wretchedness of this kind of life, would, in time, suggest to some the advantage of accumulating herds, and

flocks of gregarious animals, as an easier means of subsistence; and the consequent association of their owners to protect them from plunder.

A still increasing population led, at length, to the cultivation of the soil; and, consequently, to its appropriation. This obliged mankind to live in fixed habitations, and laid the foundation of political associations.

Many appear to have been the ages that passed away without a ray of science. Rude practical arts were gradually produced by necessity or chance. But the gratification of the appetites and passions, appear long to have been the only science cultivated, or thought of.

The consequence of political institutions is, that men slide, or are forced into classes. Those who have property, are relieved from daily labour, and are at leisure to indulge their taste for luxury, or for contemplation. The poor are relieved from their precarious situation, by administering to the wants or the fancies of the rich. The boasted wisdom of the Chaldeans and Egyptians, appear to have consisted in observations upon the motions of the heavenly bodies, for which the situation of their country was favourable; and in astrological predictions. It could not deserve the name of science.

For almost four thousand years from the creation, the human mind, sometimes cramped by slavery, sloth, and want, sometimes driven backward into barbarism by violent revolutions, scarcely approached the regions of true science.

At length, the little republics of Greece burst upon the world like a meteor of uncommon splendour. In a short space of time, they carried the sciences of language, poetry, and eloquence, to the highest perfection. In architecture and sculpture, they stand equally unrivalled. Theology, ethics, morals, mathematics, and natural history, were not neglected by them, nor by their various colonies. Happy would it have been for them, and for mankind, had they known

how to value and protect that liberty, and those institutions upon which their greatness was founded. Abandoned to licentiousness, they taught a crafty tyrant to conquer them; and through them, the rest of the world. Chemical philosophy was unknown, and nearly unthought of, either by them or by their subsequent masters, the Romans.

Chemistry appears to have first come into notice among the Arabians, as an assistant to medicine. The changes and mutations that it produced in the properties of bodies, favoured a notion that seems to have previously existed, of the possibility of converting other metals into gold. Alchemy became a general study. Experiments succeeded to experiments; bodies were composed and decomposed, in every fanciful way; but, as may be supposed, without any rational system, or attainable object. This illusive *science*, as it was called, was carried on by Christians, as well as Mahomedans, during several centuries, with an avidity, mystery, and ignorance, unparalleled.

In the mean time, the speculations of Aristotle and Plato were misapplied in the schools; and the study of nature was almost wholly forgotten in the search for unknown elements or essences, of which nothing could be known beyond the bare possibility of their existence; since our senses are not capable of perceiving them.

All our knowledge of the material world is obtained through certain material organic structures, that are admirably adapted for their peculiar purpos[illegible] but convey to the soul a knowledge of certain qualities [illegible]ly; and the extent of their power is confined within certain boundaries. By the sight, light is perceptible when its rays are accumulated in a certain quantity. By the sense of touch, bodies, when of a certain magnitude, are perceptible by the resistance they offer. We can feel, and perceive their resistance and texture, as to the hardness or softness, roughness, smoothness, and figure of their surfaces. By the hearing,

we perceive the sounds produced by vibrations of the air, or of elastic and sonorous bodies. The organ of taste enables us to perceive certain agreeable or unpleasant sensations from bodies that may be applied to the palate; and on the organ of smell, peculiar sensations, which may be agreeable or disagreeable, are produced by vapours or minute particles floating in the air.

The soul or mind of man is shut up within a certain organized body of matter. He may think, reason, imagine, or exert his other mental faculties: he may exert the powers of locomotion that his body is furnished with; he may apply his senses to the subject of his sensations as long as he pleases; by continued industry and attention, he may improve the use of them, and extend his powers of perceiving minute differences among their proper objects respectively; by practice, he may, perhaps, somewhat increase their boundary. The eye of a watch-maker, for instance, seems to be sensible to minute objects, with more distinctness than that of a wheel-wright, but he can obtain no knowledge of the material world except through them. They are the only windows of the soul, through which it can obtain any knowledge of matter, or of its properties. Whatever other simple properties matter may possess, that cannot be conveyed to us through the medium of these senses, must remain unknown to us.

The man who has the misfortune to be born blind, or deaf, or without the sense of touch, or of taste, or of smell, can have no knowledge, nor even conception, of the properties affecting these organs respectively. If he be induced to reason upon them, his reasoning must be like that of the blind man who at length discovered, that the colour scarlet resembled the sound of a trumpet.

It may startle with surprise those who are unaccustomed to contemplate the nature of our sensations, and of the perceptions they produce in us, to tell them, that the infor-

mation they convey, is not so direct and simple as it appears to be at first sight; and that we often fall into error from an ignorance of this fact: not from our senses deceiving us, as the phrase is; but from our judgment deceiving us, where appearances are similar.

We talk, for instance, daily and hourly, of seeing bodies; but, in strict truth, bodies are not objects of sight. If any one doubt of this, let him ascend a lofty eminence in a dark cloudy night. Let him then look at, and, if he can, see the bodies around him. The fact is, light only is visible.

When the rays emanating from the sun, or any luminous body, fall upon an opaque body, it has the property of partially separating the primary colours, and of reflecting a part of them to the eye of the observer, producing a modified colour and appearance. The perception thus produced by the rays of light, we impute to the body.

In ways that are equally indirect, different properties of matter act upon our other organs of sense, and produce different perceptions. And, in the course of chemical inquiries, it is frequently observable, that very different bodies produce corresponding perceptions; and that sometimes bodies, whose compositions very nearly approximate, produce very different perceptions: no explanation can be given why these things are so. But to ascertain the identity of a body, it is necessary to examine a number of its properties. Thus a bright yellow shining mass may be gold. We try its fracture, its scratch, its toughness: if we still think it to be gold, we try its specific gravity, and the action of aqua fortis upon it; if aqua fortis does not act upon it, and its specific gravity is above nineteen times greater than water, we are satisfied that it is gold; because we do not know of any other body that has the same collection of properties.

The phenomena thus appearing to the mind, it is able to contemplate and compare together; it is able to notice their analogies and their diversities; their changes, and the cir-

cumstances attending them; frequently to observe, or trace the causes producing them; to draw inferences from, and to reason upon them; sometimes justly, but often erroneously.

The material world is made up *apparently* of an immense number of minute particles, or atoms. They are far too minute in size to be perceived individually, or to be in their individual state an object of knowledge. All that can be said about them is mere conjecture, or vague inference. One philosopher thinks that matter consists of minute particles, and may be divided to infinity: another, that it is made up of solid, indivisible, impenetrable atoms, that are of several kinds respectively, and of peculiar shape. Some think that they are not impenetrable, but that they are defended by certain attractive and repulsive forces, acting at certain distances, and in certain ratios, increasing as their centers approach. Some philosophers imagine that there must be ultimate homogeneous solid particles of matter, of one, or a very few kinds, only; and that these, by certain peculiar combinations, produce the different material elements we are acquainted with. Others imagine that the primary elements of matter are numerous, and permanently distinct from each other.

It must at all times be remembered, that opinions do not constitute knowledge; on the other hand, they frequently lead away from it.

It is a just and necessary axiom in chemistry, to consider every distinct body that has not been decomposed, as a primary chemical element. When, in the course of investigation, any one of these supposed primary elements is decomposed, it is removed to the rank of the secondary chemical elements, and the newly discovered element, if any has been met with, assumes its place.

Under these circumstances, it is not to be wondered at that the study of Physical Philosophy was late in its com-

mencement, and slow in its advance. When at length it attained something like a consistent appearance, it was retarded, during many ages, by philosophers mistaking their own powers, and wandering after occult causes, and unknown essences, which could not be perceived by the senses, nor comprehended by reason. Fancy and imagination usurped the place of experiment and induction; sophistry, cavilling, and a confused jargon of words, was substituted for just reasoning; and many ages were employed in ringing changes, according to art, upon empty sounds. He who could cavil best, was considered as the most learned man.

This error has at length been discovered; the extent and nature of the human faculties are now better understood. It is now well known, that the only way in which it has pleased the Creator that man shall learn the laws of nature, is, by a close and patient attention to its phenomena, by the multiplication of experiments, and by comparing and making inductions from them.

By pursuing this plan, an immense mass of knowledge has been accumulated. The labourers have been rewarded beyond their most sanguine expectations.

After considering what a barbarous unthinking being an uncultivated savage is, what human mind can contemplate without astonishment, the stupendous mass of science, both speculative and practical, of arts, both useful and ornamental, the laws, policy, and literature, that has gradually been created, established, and improved, by the succession of a race of beings, apparently so helpless and transitory.

In the fathomless depths of the south sea, a race of animalculæ, too minute almost for man to see, has, in like manner, by the labour of its numbers, and successive generations, gradually raised superstructures that now project above the surface of the ocean, and form islands that are sufficiently extensive, and luxuriant in vegetation, to

serve for the abode of man. Both animals have obeyed the powers, propensities, and instincts given to them by their Creator: both, perhaps, have equal merit in so doing; but the demand upon their gratitude is not equal.

Chemistry is now reaping the benefit of this application to experiment; and is repaying its cultivators with ample rewards. Now, the philosopher's stone is found to consist, like the husbandman's hidden treasure, in industry and attention. The united labours of a number of scientific Chemists, throughout the different nations of Europe, in the pursuit of discovery, by numerous series of experiments, conducted by analogies, and attended with close reasoning and careful inductions, have raised Chemistry into a general science, supported upon an extensive mass of facts, and embracing the properties of every kind of matter, and of the agencies acting on it.

This branch of science now extends its assistance to every other branch; and, in one way or other, to all the useful and ornamental arts and manufactures. The various improvements it is daily suggesting, are productive of the most signal advantages, and contribute extremely to *preserve the health*, and to promote the comfort and happiness of man.

When persons unacquainted with chemistry have heard of any particular discovery, no uncommon question has been, What is the use of it? The question is generally premature. It is seldom that all the applications of a new discovery can be seen at once. Every discovery is an addition to the general stock of natural knowledge; from this stock, selections of data can be made, and daily are made, and applied according to the contingencies and wants that arise, and the abilities of those who apply them.

The discovery of the composition, and of the explosive quality of gunpowder, has, it is probable, been known in the East for ages; its application to war is of comparatively

recent date. So far was its real value, as an instrument of war, from being duly appreciated on its first introduction, that it was esteemed as a baneful engine, sent by heaven, in its wrath, to enable mankind more speedily to murder, and destroy each other.

It is not our business here to investigate moral causes; nor to inquire why ambition was given to such an ephemeral being as man is; nor why wars and bloodshed have always prevailed among rival nations. History tells us it always was so; and observation shews, that it is likely always to be so. History tells us further, of the numerous deadly feuds between individuals and families of the respective nations, that arose out of the personal manner in which wars were formerly carried on; and which were kept alive long after the national quarrels had ceased. A war was frequently little else than a succession of individual combats and murders. All the brutal and revengeful passions were harrowed up in the soul; and the cause of the war, frequently a slight one, was oftentimes forgotten in the individual contentions of private revenge. Physical barbarian strength, and hardy capability of privation, lorded it over the field. The debilitated inhabitants of luxurious half-civiled nations, fell an easy prey to every daring barbarian. Neither science nor industry could provide a secure barrier against savage cupidity and ambition.

What is now the state of the world? The soul of man is as restless and ambitious, and national wars are as frequent as ever; but war is no longer a contest of mere brutal force, and personal strength. A skilful application of gunpowder, to give force to projectiles, has converted war into a science. Its conduct requires the knowledge of other sciences, and of various arts; and the cultivation of all these cannot take place without civilization. The consequence is, uncultivated barbarism is easily repelled within its own bounds. The wars between rival nations now no

longer involve the inhabitants of these nations in individual feuds; when private feelings do interfere, it is more generally on the side of humanity. In the last continental wars, of twenty-five years in duration, involving nearly the whole of the civilized world; attended at times by every species of brutality, destruction, and misery; and by numerous individual acts of prowess; occasioning too the death of thousands, and the ruin of millions;—how few are the instances of private feud and animosity between the subjects of respective nations.

Making every allowance for the improvement in modern manners, and for the polish it has thrown over human passions, could such a change have happened had gunpowder been unknown?

Arguments are not necessary now to shew the advantages and importance of chemical science. It is becoming a subject of general attention, and a branch of liberal education. A chemical philosopher was formerly a sort of wizard, a monster rarely to be seen; and then, in his gown and cap, or enshrined in the cloister of the university. It was his dread lest the vulgar should understand him; lest, while he pretended to dazzle, and to be great, he should chance to be useful. These contemptible feelings are now vanished, and chemists are running to an opposite extreme. Not only are treatises of Philosophy and Chemistry met with in every quarter, but beaux, ladies, all are now chemists, or pretend to be so. All are vying with each other in the ardour of experimenting, and communicating: monthly, and even weekly journals are teeming with experiments, and with real or supposed discoveries. They are poured forth in boundless profusion, and in all shapes; some of them over and over again, frequently like the fabulous snakes and rats produced from the mud of the Nile, they are sent forth into the world with their heads or their tails half-formed, while the remainder is still in chaos.

At the same time, this thirst for investigation, when governed by sense and ability, is producing curious, valuable, and useful discoveries. The institutions that are established in London, and in several large towns of England, for the general extension of experimental philosophy, are certainly most deserving of public encouragement. They have contributed much towards spreading a general taste for that kind of knowledge, and towards explaining its application, and advantages in arts, manufactures, and domestic life.

DIVISION II.

ON MATTER GENERALLY.

Article 1. General Observations.

When a man begins to use his powers of observation, and to examine with attention the bodies around him, they appear to be innumerable. They are variable in distance, magnitude, number, figure, and colour; they vary also in structure, hardness, softness, and other varieties of texture; they are solid, fluid, or gaseous; some are tangible, others intangible; some are visible, and others invisible; some are in motion, others at rest. He perceives at times the actions of certain agencies upon these bodies, in a manner that is to him incomprehensible. All this profusion of bodies and motions appears at first to overpower the mind, and to elude research. We are amazed at the demonstration of power and wisdom that pervades every where; and are perplexed by the various changes we perceive to be going on, while we perceive no creative power, and are ignorant of the exciting and final causes.

A more close and continued attention shews us, that many of these bodies have similar properties; and that others resemble each other in various degrees, and in certain respects only. Hence we come at the knowledge of gravitation, figure, texture, and other general properties. According to these general properties, we arrange and classify bodies. Thus the diversity that appears so perplexing at first, gradually slides into order, until we arrive at individuals. There the mind is able to investigate singly. By

comparing and diversifying experiments made upon them; and by pursuing phenomena through all their complications and labyrinths; comparing their analogies, and drawing close and cautious deductions from them; is built up that mass of knowledge, which is now called the science of nature.

Our business is with that branch of the science of nature, which is called chemical philosophy. The object of chemical philosophy, is the actions which the atoms or minute particles of heterogeneous matter exert upon each other.

The Chemist is acquainted with a certain number of material undecomposable bodies, that differ from each other in various properties; while they all agree in some few, which are, in consequence, more general. By virtue of the properties wherein they agree, they are all classed under the general term matter; and by virtue of the properties wherein they differ, they are supposed to constitute different elements. We are not prepared to assert that they really are all of them, different material elements, but merely, that since we have not been able to decompose them, they are so to us. We qualify the name, therefore, by naming them CHEMICAL ELEMENTS. Some of them, nay, all of them, may, for aught the Chemist knows, be compounds; but until they have been decomposed, he is justified, both by necessity and by logic, in considering them as chemical elements. The bodies at present considered by Chemists as distinct material elements, are the following.

1. Oxygen
2. Chlorine
3. Iodine
4. Hydrogen
5. Nitrogen
6. Carbon
7. Sulphur
8. Phosphorus
9. Boron
10. Selenium
11. Fluorine?
12. Potassium
13. Sodium
14. Lithium
15. Barium
16. Strontium
17. Calcium
18. Magnesium
19. Aluminum
20. Glucinum
21. Ittrium
22. Thorinium
23. Zirconium
24. Silicium
25. Molybdenum
26. Tungsten
27. Titanium

28. Columbium	36. Lead	44. Platinum
29. Chromium	37. Tin	45. Rhodium
30. Antimony	38. Iron	46. Palladium
31. Arsenic	39. Manganese	47. Osmium
32. Tellurium	40. Cerium	48. Iridium
33. Cadmium	41. Uranium	49. Silver
34. Zinc	42. Nickel	50. Gold.
35. Bismuth	43. Mercury	

This must not be considered as a complete list of all the chemical material elements. It is highly probable that, as the science advances, many of them will be decomposed into elements still more simple. Indeed, such is the obscurity of this part of science, for reasons already adverted to, that every one of them may be compounds of elements still more simple. Phenomena are perpetually appearing, which are not explicable in the present state of knowledge, and which ought to humble a little the pride of science.

Many of these elements exist in great abundance, and make up the principal part of our globe: and, probably, of the whole solar system. At least, we know that the bodies composing it have, in common with earthy matter, the properties of gravitation, opacity, and of reflecting the rays of light that fall upon them. A great number of these elements are very rarely met with, and in small quantity. Some of them, many of the metals for instance, have been known for ages; but the strong attractions that the greater number of them have for each other, the strong disposition that the most general and most active of them have to combine together, long concealed the most important of them from common observation; except in a state of combination, as primary and secondary compounds. The consequence is, that the greater number of chemical elements are of comparatively modern discovery, and the result of accidental observation, verified by experiment in

the chemist's laboratory. It is most probable, too, that elementary bodies, still undiscovered, are existing in natural combinations; and will be brought to light as the science advances.

Besides these elements now spoken of, and which all philosophers agree in calling matter, there are other agencies, which we observe to be in constant action upon matter; variously affecting, modifying, and changing its state, properties, attractions, and combinations. Their agency is very powerful and extensive; both in the great laboratory of nature, and in the laboratory of the chemist. It is necessary, therefore, that the chemist be acquainted with what is known of them, and their properties. These agencies are Light, Heat, Electricity, and Magnetism.

It is proposed first to speak of those physical properties which, although modified by circumstances, appear to be general to all matter—to all the chemical elements above-named—and ought to be understood by the chemist: then, to examine those general agencies which, by their general presence, in various degrees, very much affect and modify both the mechanical and chemical properties of matter. Our inquiry shall then be extended more generally to the laws of chemical attraction; and, lastly, we will examine the properties of the chemical material elements severally; their primary, and the most important of their secondary compounds.

Whether all matter, as some philosophers have supposed, is composed of one simple elementary agent; or of a very few agents, differently compounded and modified, to produce the bodies esteemed as chemical elements, cannot be known, and must not be assumed without proof. It must be remembered, that we have no knowledge of matter except through the medium of our senses; or what may be derived as necessary consequences, from the phenomena represented by them. By our senses, we can examine

matter in masses only; we cannot perceive its elementary points or atoms, nor judge what might be their properties, if individually insulated from each other, and from every other agent.

Article 2. On Extension.

All matter is extended; or necessarily occupies a certain portion of space. The space it occupies is, of course, in proportion to its volume; and is bounded by surfaces, which, at the same time, define its figure.

Article 3. On Impenetrability.

The particles, or atoms of which a mass of matter is composed, are supposed to be impenetrable. Masses of matter certainly are impenetrable to other matter; but whether they consist of solid impenetrable atoms, or of minute particles surrounded by a repulsive power, that increases, in a certain rapid ratio, as a force approaches their centres, seems doubtful. In either case, the proposition seems to hold good, that the particle A cannot occupy the space already occupied by the particle B, without expelling B from it. At the same time, it appears, that in aggregate masses of matter, however dense, solid, or hard they may appear, the particles or atoms are not every where in absolute contact; but are retained, by a certain force, according to certain arrangements that are unknown, and that appear to differ in different bodies; and even in the same body according as it is affected by heat and other agencies. It appears that the resistance to the pressure of the finger in touching a body, commences before it comes into absolute contact; and that

the rays of light are reflected when they arrive at a minut distance from a surface.

Article 4. On Inertia.

Inertia is a physical property of matter. It means more than that a mass of homogeneous matter is perfectly inert. When in a state of rest, it has no power to move itself, and when in a state of motion, it has no power of stopping itself; but would, if gravitation were suspended, continue moving on through space, in a right line, until retarded by an external force.

Article 5. On Divisibility.

Some philosophers suppose matter to be divisible, without end; while others suppose that it consists of certain minute atoms that are alike impenetrable and indivisible. There is nothing to guide the mind here but probability and remote inference. It seems to be highly probable that simple elementary matter consists of minute atoms, possessing certain polar actions, or repulsions and attractions; and that when two heterogeneous particles combine chemically, they produce a single compound atom, which appears to have in its turn a single attraction and repulsion. If so, this compound atom must have a certain magnitude, and as a compound, must be indivisible; for to divide it would be to decompose it. Now it is contrary to all experience for a chemist to decompose any compound body by mere mechanical division.

In practice, however, some bodies may be reduced in a wonderful degree and still be perceptible. An ounce of

gold is usually plated upon a cylinder of silver for the formation of gold lace, and is drawn out into a wire so fine as to extend three hundred and thirty miles or more in length; and the wire is uniformly covered with gold. When it has been flattened, each inch may readily be divided into one hundred and ten equal parts. Each grain of gold may thus be divided into ten millions of parts, visible to the naked eye. Under a microscope they may again be subdivided to a considerable extent, and still the surface of the silver appears uniformly covered with gold; and yet it is unknown how far we are distant from its elementary atoms.

Dissolve one grain of carmine in an ounce of distilled water: into another ounce of distilled water drop one drop of the solution, its weight will be under half a grain, and will contain nearly a thousandth of a grain of the colouring matter. The red tint will be visibly diffused over every visible portion of this second solution. Each drop will contain a millionth of a grain, and may readily be divided into ten visible parts.

The light particles of odoriferous bodies escape, and are diffused through the surrounding air, and arriving in contact with the organs of smell, produce their peculiar effect. One grain of musk will keep the surrounding air impregnated with its flavour for several days, with very little sensible loss of weight; and yet the air is escaping and carrying it off all the while. The particles, or atoms, must in this case be minute beyond all calculation, and probably are so in all cases.

Article 6. On Gravity.

Matter is well known to have weight, that is, to gravitate or be drawn with a certain force towards the earth's centre.

This attraction of gravitation is found to act between the minutest particles of matter, and between the largest masses; and to act with a force which is in direct proportion to their respective quantities. It acts at all distances but as the distance is increased, the force of attraction decreases, in a proportion that is equal to the square of the distance.

This force is almost imperceptible between small masses of matter. But a large mass of matter, the earth for instance, has a very sensible action on small bodies that are upon or near its surface, producing what is called their weight. The gravitating attraction of the earth, or of any large mass of matter, acts upon bodies that are on its surface as if the whole of the attractive force acted from its centre. All parts of the surface of a globe are equidistant from the centre. As the earth is nearly globular, the attraction or weight of bodies is nearly the same all over it. It is considered as a constant force, and is supposed to be equal to the quantity of matter that the bodies respectively may contain.

The same attractive force acting between the immense masses of matter that constitute the sun and the various planets, balanced by a centrifugal or progressive force tending to propel them in right lines; retains the whole system, and governs the respective revolutions.

Article 7. On Specific Gravity.

Bodies vary from each other in the relation existing between their volumes, and their gravitating attraction. Or, in other language, bodies differ in their density, and contain in an equal volume very different quantities of gravitating matter. Thus, a given volume of gold will weigh more than nineteen times as much as the same volume of water; and a given volume of water above eight

hundred and twenty times as much as a given volume of atmospheric air. The particular weight of each body, in comparison to its bulk, is called its specific gravity. Pure water is usually assumed as a standard, and called unity or 1.00. It is easy to compare all other bodies with it, by weighing an equal volume of them. This may be accomplished in different ways, according to the properties of the bodies to be examined.

Metals and bodies that are heavier than water, and insoluble in it, may be weighed in the air, and the weight noted. Then they may be weighed in water, and the weight noted. The difference between the two weights is the exact weight of an equal volume of water. The weight in air of the body compared to that of the water, is its specific gravity.

Solids that are soluble in water, may be weighed in alkohol, or in an oil: then the different specific gravities of the oil and water calculated, and allowed for.

Solids that are lighter than water; after being weighed in air, must be attached to a heavier solid, of known weight, and specific gravity; and of such a bulk that they may both sink in the fluid. The specific gravity of the lighter body may then be found by a simple calculation.

The specific gravity of liquids is best ascertained by weighing equal volumes of them, and of pure water, in a small light bottle with a narrow neck, marked with a file near the middle of it; to which mark it should be always filled.

When great accuracy is required, attention must be paid to the temperature of the different bodies employed in the experiment; and compensation made for the respective deviation from a certain standard. But, when it can be done, it is generally most convenient to let them all attain the temperature of the atmosphere, in which the experiments are made.

The specific gravity of gasses may be obtained by weighing them in a light glass balloon, of known capacity. The balloon may be weighed while full of atmospheric air; it must then be exhausted by an air-pump, and again weighed. Then it must be filled with the gas to be examined, and its weight noted. A due compensation being made for the imperfect exhaustion of the balloon, and, if necessary, for variation of temperature and barometrical pressure; the weight of it is then compared with that of the same quantity of the gas used as a standard. This standard gas is generally hydrogen or atmospheric air.

The specific gravity of water at 60° being - - 1.000
That of dry Hydrogen gas at 60° Barometer
30 inches is nearly - - - - - - - - - - 0.000085
That of dry Atmospheric air - - - - - - - - 0.00122
Or the specific gravity of Hydrogen being - - 1.
That of Atmospheric air is - - - - - - - - 14.4
That of water is nearly - - - - - - - - 11800.

Article 8. On Cohesion.

Hitherto, matter as been spoken of as if it consisted of loose particles or atoms retained together by mere juxtaposition, or by their gravitation—their weight. Were this the only force that operates, the world would be a mere chaos, a mere ocean of dust. Texture, definite figure, plasticity, hardness, almost all the mechanical properties of matter, as well as the laws and properties connected with them, would be wholly unknown; or, at least, be mere creatures of intellection. The bodies around us we observe to be in various states of consistence. Some are in the state of hard solids, from these there is a progressive change to softer solids of various kinds; some are hard, rigid, brittle, and inflexible; some fibrous, tough, and flexible; others are yielding in all direc-

tions: from these there is a gradual approach to the liquid state; and in liquids the degree of fluidity is very different. Other bodies again appear in the state of gasses or air,—fluids that are extremely light, rare, elastic, generally invisible; and having other remarkable properties.

The state in which these bodies are first observed by us, we naturally enough suppose to be their usual, or native simple state. But every thing we behold is, in common with ourselves, immersed in caloric, electricity, and in the atmospheric air, which presses upon us, and all around us, with a considerable force. These circumstances greatly influence the state of bodies—of liquids and gasses in particular. It is highly probable that, could the action of these agencies be suspended, every body that we now see in the state of a fluid, or a gas, would become a solid. It is known that a number of them would.

Of the primary chemical elements under the temperature and pressure of the atmosphere, forty-five are solids, one—chlorine—doubtful: four of them are gaseous; and none of them liquid. But chlorine is easily reduced to a liquid state by pressure, and diminution of temperature.

Of the cause or power by virtue of which different kinds of matter are able to cohere, or to assume different and peculiar textures, we have no knowledge; we know merely that it is so, and that it is powerfully affected and varied by caloric.

This cohesive attraction is regulated and balanced by a repulsive power, of which our knowledge is equally obscure. We perceive its existence, and that it is increased by caloric. It would appear that each minute atom of matter possesses a certain kind of polarity, and that certain corresponding parts of the same atoms are mutually attractive or repulsive of each other; and that these respective properties are affected by the agencies of caloric, electricity, &c.

It is the opinion of many philosophers, that the attrac-

tions of gravitation, cohesion, and chemical attraction also are merely modifications of the same force; and that the repulsive force observed is merely dependent on the presence of caloric. It may be so, but they appear to us as being perfectly different. They are subject to apparently different laws, and are productive of different phenomena. It is logical, therefore, as well as convenient, to consider them as different until their identity be proved.

It is astonishing to observe the very numerous varieties of texture with which different kinds of matter are endowed to fit them for the various applications they seem to be intended for; and the facility with which they may be applied by man to his various uses. There is hardness in every degree and gradation, united and modified with every variety of toughness, rigidity, brittleness, elasticity, malleability, ductility, flexibility, resiliency. Indeed, the form and manner of cohesive attraction is varied in almost every possible way. In many cases it is imparted to other bodies by combination, producing valuable alloys. Frequently it altogether disappears, being merged in the new properties of the compound.

Article 9. On Crystallization.

When a solid body is reduced to a state of liquid; whether it be from solution in water, or, as in the case of metals, by caloric alone; its atoms are set free, moving over and floating upon each other. They can now obey their own attractive and repulsive forces. The consequence is, they assume an arrangement that is peculiar to them; and as the heat, or liquid, is slowly abstracted, they again cohere into a solid, that has its own peculiar form and texture, which is more or less distinguishable; and by which they may generally be distinguished from each other.

This property is called crystallization: it is a very general property. It appears to be the general source of cohesion in metals and compound minerals. It is liable, however, to be modified by various circumstances that favour, retard, or obscure it.

The crystallization of spermaceti, and of the more fusible metals, is easily demonstrated. Let fused bismuth, or zinc, for instance, be suffered to cool very slowly in a still situation; and when the surface is solidified, let it be suddenly tapped, the central part being yet fluid, a beautiful surface of crystals will be left; each body having its own peculiar geometric form, with definite plane surfaces and angles. The crystallization of different bodies takes place in different ways, according to their respective properties. Most of the compound minerals offer themselves crystallized in more or less regular crystals; some of them in great abundance; and most amorphous masses of matter shew distinct appearances of having been crystallized. The crystallization of many bodies appears to have been the operation of years, and even of ages. Others appear to require a mass of matter, or a quantity of menstruum, accumulation, or continuation in the application of caloric, that cannot be commanded by art. Others again appear to require a knowledge of particular circumstances that are yet unknown.

In the chemist's laboratory crystallization is very limited: it is confined, in a great measure, to soluble watery saline solutions.

The saline body to be crystallized, is dissolved in a proper quantity of menstruum; and as most of these bodies are more soluble in hot water than in cold, when a saturated solution is placed in a situation where it may cool slowly, the crystals form as the liquor cools.

There are several collateral circumstances that are found to favour or retard the formation of crystals. A cool, clear,

dry air, with a light wind, favours crystallization; partly from its low temperature, and partly, perhaps, from the electric state of dry air. Light favours crystallization. If a partial light fall upon a crystallizing solution, the greater number of crystals will form on the part on which the light falls. The peculiar electric state of the surrounding air, has also an influence upon crystallization. A damp, close, or warm state of the air, are unfavourable to crystallization, and sometimes altogether prevent it.

Different bodies are soluble in different proportions of water. When water is saturated with one salt, it will often dissolve a considerable portion of another.

The salts that are mixed in a saline solution, may be separated by means of the difference in their solubility. When a saline solution is concentrated to a certain point, by evaporation, a quantity of the less soluble salt will separate on its cooling; it may then be evaporated to obtain the more soluble salt. As the liquor is further evaporated the crystals of the less soluble salt may, the greater part of them, be picked out. The respective salts are then further purified by re-solution and crystallization. When salts that are of nearly equal solubility, are mixed in solution, the priority of crystallization is sometimes determined by adding a few ready formed crystals of one of the salts.

A nucleus or basis of attraction is sometimes useful, and a few cross sticks or strings, or, as in the case just adverted to, a few ready formed crystals are placed in the liquor. The privation of air in some cases appears to retard crystallization.

Perfect rest appears necessary, that the minute atoms of the salt may arrange themselves in the fluid; but the *further* movement to produce their cohesion appears to be retarded for a time, by the consistence of the fluid perhaps, or by the atoms being too numerous to have a perfectly free motion.

Thus, a concentrated solution of Glauber salts, when slowly cooled, in a still place, will not crystallize: upon drawing the cork the crystals will shoot rapidly, and will continue forming until the whole is a solid mass. Sometimes, upon drawing the cork, crystallization does not take place until a slight jerk or agitation is given to the solution, and then commences.

Some salts are nearly equally soluble in water at any temperature above 40° Farenheit. This is the case with common salt. It is usually separated from its solutions, by raking it out of the boiling liquor during the evaporation; and when the mother liquor becomes loaded with the more soluble salts, they may be crystallized by suffering the liquor to cool.

When crystallization proceeds favorably it does not stop at the point of saturation, but leaves the mother liquor somewhat diluted and capable of re-dissolving a part of the salt; and in consequence, if the crystals are not removed in due time, their edges are re-dissolved.

Sugar is soluble in water in different proportions according to its temperature; as the temperature falls, a saturated solution crystallizes. The solution is then left so diluted, that upon a slight elevation of temperature it ferments. There is, however, a precise point of saturation known to confectioners, at which cold does not produce crystallization, nor warmth fermentation.

Some saline solutions are decomposed by heat, and then the necessary evaporation must be produced by absorption and evaporization in an air pump vacuum; as will hereafter be explained.

Sometimes the cohesive attraction, or the disposition to crystallize, existing among the particles of a salt, is prevented from acting by the stronger attraction of the water. In this case the attraction of the water may be diminished by the addition of alkohol, or of some other body; or the

menstruum may be altogether changed. A solution of pure potassa in water, can hardly be said to crystallize:—if dissolved in alkohol it produces regular crystals.

Some bodies do not become liquid, but pass at once from a gaseous to a solid state, assuming, at the same time, a regular crystalline cohesion. This is the case with iodine, carbonate and muriate of ammonia, benzoic acid, and many other bodies. Snow is produced in this manner.

Many crystals are extremely hard, and in their aggregate masses perfectly insoluble in water; but the chemist can, in his laboratory, reduce most of them, by the application of certain chemical forces, into a state more or less soluble. In the immense laboratory of nature, all mechanical and chemical agencies are brought into action with immense force; and solution in consequence may be more perfectly effected. Many of these crystals, from their hardness and insolubility, must have been years, or even ages in forming. The greater number have excluded all water from their composition; some few even of the most insoluble, retain a portion, apparently as a component part.

Such of these bodies as are readily soluble by art, are commonly called saline compounds. They are generally crystallized in the laboratory, with more or less facility. They are soluble in different proportions of water, and retain different proportions of water in their crystals; those which are most soluble generally retaining the largest proportion. Thus water, or a certain part of it, forms in most of these cases a component part of the crystal; and when separated, the crystal falls into powder. In some salts the water of crystallization is in small quantity; in others it is in so large a quantity as to constitute half the weight, or more, of the crystal. Then it frequently happens that the crystal becomes a liquid, upon exposing it to a heat below 212°, the salt becoming soluble in its own water.

The crystals of some saline bodies retain the water of crystallization with a very slight force, and part with it very readily by spontaneous evaporation on exposure to the air; the salt then falls into powder, the cohesion of the crystal being destroyed.

The crystals of some saline bodies, on the contrary, absorb an additional quantity of water from the air, and are dissolved into a liquid by it. The former phenomenon is called efflorescence, the latter deliquescence.

The attractive force of some salts for atmospheric vapour, is so nicely balanced with that of the air, that they attract water from the atmosphere when it is damp, and give it out again when the atmosphere is dry.

Efflorescent crystals are often preserved unchanged, by covering them with a thin coat of oil, and then keeping them in well closed bottles.

Every body that is capable of crystallizing, and that seems to be every body that is capable of a liquid and of a solid state, has a tendency to assume a peculiar texture, consequent upon a certain arrangement of its atoms; and its crystal assumes a certain peculiar form. Common salt, for instance, crystallizes in cubes; carbonate of lime in rhombs; common nitre in six-sided prisms; alum in octoedrons. Crystals are small, irregular, and confined in figure, when hastily crystallized: when slowly crystallized, they are larger, and their characters more perfect. They may be obtained still larger, and of greater beauty, by selecting the finest of a group of crystals, and placing them in a concentrated solution of the same salt. The exposed surfaces attract additional particles, which will arrange themselves according to their proper law. The crystals require to be frequently turned, and the liquor to be often changed for a concentrated solution; that the edges may not be acted on. In this way, large handsome crystals of most of the saline bodies will at length be produced.

The examination of the structure and forms of crystals, and of the laws that govern their formation, has produced the science of crystallography.

It has long been well known to lapidaries and mineralogists, that they could cleave or break crystals more readily in certain directions than in others; and that the cleavages were more smooth and even. The Abbé Hauy, in inquiring into the source of this property, was led to the discovery that various complicated, and apparently diversified crystals of the same mineral, may, by repeated cleavages, be reduced to one simple primitive form of crystal, or nucleus; which is proper and general to that mineral, whatever may be the form of its secondary crystals. This simple primitive crystal may, in the same manner, be subdivided as far as the eye can reach. By this means he arrived at the smallest visible crystal having a regular geometric form. To this he gave the name of integrant molecule, supposing its form to be governed by that of its elementary atom. Thus, the crystals of calcareous spar, which occur in certain various secondary figures, produce a rhomboid as their primitive form. The primitive crystal of fluor spar is an octoedron; that of common salt a cube.

The larger or secondary crystals of minerals, and also of common saline bodies, are produced by a superposition of laminæ of the integrant molecuke, or rather of atoms, upon the primitive crystal, or nucleus. But they are found frequently to assume different forms, in consequence of different mixtures in the menstrua, or of other contingencies modifying them, and producing a diversity in the increments and decrements upon their surfaces, edges, and solid angles.

The primitive forms of crystals have been reduced to six. The parallelopipedon, the tetraedron, the octoedron, the hexaedral prism, the dodecaedron with rhomb surfaces, and the dodecaedron with triangular surfaces.

The primitive crystal, or nucleus, may be reduced by cleavage to its integrant molecule. The primitive molecule is not necessarily of the same figure as the primitive crystal. Their figures may be reduced to three: the tetraedron, the triangular prism, and the parallelopipedon.

It is thought by Dr. Wollaston, and others, that the integrant molecules may be made up of spherical atoms, or of obolate or oblong spheroids; and, it is said, that the various crystalline figures in which different bodies appear, may be accounted for more satisfactorily upon this supposition than upon any other. This hypothesis might be extended; for if the force of cohesive attraction acts, as that of gravitation does, with increasing force as the centre is approached, the different degrees of hardness in bodies would be in proportion as their respective atoms should be more or less spherical or flattened.

But nothing is known of the size or shape of the primary atoms of matter. It appears from several phenomena, that in solid bodies they are not in absolute contact.

Every crystallizing body appears to produce, as has been said, its integrant molecules, and its primary nucleus of a particular form; while the secondary crystal is sometimes variously modified; but these modifications are still bounded by particular geometric figures, surfaces, and angles: and minerals may, very generally, be discriminated by them. So that, in the examination of minerals, an attention to these points is essentially necessary.

For an accurate admeasurement of the angles, the goniometer of Mr. Adelman, and the reflecting goniometer of Dr. Wollaston, are far superior to every other instrument.

Another method of developing the structure of crystals has lately been pointed out by Mr. Daniel.

When a lump of alum is immersed in four or five times its weight of water, after three or four weeks it is found to have assumed a pyramidal form; a larger portion having

been dissolved from the upper than from the lower part. The lower part of its surface will be covered with sections of octaedrons, more or less perfect, in relief. A piece of borax, treated in the same manner, will be covered with sections, more or less perfect, of eight-sided prisms. Carbonate of baryta, or of lime, and many of the metals may, by means of a diluted acid, be dissected in the same manner.

Article 10. On Liquefaction.

The state of matter, called fluidity, is well known. It is effected, perhaps in all cases, by the agency of caloric. If caloric be hypothetically considered as a distinct element, fluids may, as we shall see hereafter, be considered as a compound of a base and caloric.

Fluids are in two states, they may be liquid or gaseous. The particles of liquids do not exert any particular attraction or arrangement, as solids do. They are devoid of cohesion, and the cohesion varies in different liquids; they admit of a sliding motion over each other, and, when homogeneous, adhere with perfect facility when being brought into virtual contact.

The particles of liquids tend to adhere to surrounding bodies, sometimes with greater force than they adhere to each other. When the attraction for a solid is slight, the superior attraction of the particles of the liquid for each other produces an apparent repulsion. The same appearance is produced when two liquids are mixed, as oil and water for instance, the homogeneous attractions of the particles of which are stronger than the heterogeneous.

Cohesion does not take place unless the particles are brought into virtual contact. A drop of a liquid falling upon the surface of a solid for which it has an attraction, fre-

quently rolls off as if repelled, in consequence of a thin layer of dust, of some other liquid, or of air preventing contact.

When it is attempted to drop a liquid very slowly from the mouth of a dry vial, the under surface assumes a globular form; and the drop is larger as the cohesion of the liquid is greater; the shape and size of the drop being regulated by the balance between the cohesive and gravitating attractions.

If a bit of gold leaf or wire be laid gently on the surface of water, it will be supported by the cohesion between the particles of the water. Although it is almost twenty times as heavy as the same volume of water, it is not able to overcome its cohesive force. If a little ether be poured gently on the water, the adhesive force of the ether will support the wire: it will therefore pass through, but will be retained on the surface of the water. Yet ether has much cohesive force as to collect, and fall in drops, from the lip of a vial.

ARTICLE 11. ON CAPILLARY ATTRACTION.

When cohesive attraction takes place between a liquid and a solid—between a liquid for instance, and the sides of a vessel containing it, the atoms in contact are attracted a short distance upwards; this cohesive attraction overpowering gravitation in a proportion marked by the height to which the liquid is elevated. There is a balance between the cohesive attraction of the solid for the atoms of the liquid, that of the atoms of the liquid for each other, and the gravitating attraction of the latter. This balance is described by the curve formed by the surface of the liquid thus elevated.

When no attraction takes place between the adjoining

atoms of a liquid and its containing vessel, the mutual attraction which exists between the atoms of the liquid, for each other, not being counteracted, to a certain extent overpowers gravitation, and produces an appearance of repulsion. The curve on the surface of the liquid is in this case reversed.

When the diameter of the vessel is sufficiently reduced, as when a capillary tube, open at both ends, is employed, one end being immersed in a vessel of water, the resistance of gravitation is diminished, and the phenomenon is rendered more remarkable. The liquid is attracted upward in the tube, until the gravitation is balanced, provided the length of the tube admit of it; but it cannot rise above the surface of the tube, because there the attraction must cease. The finer the capillary tube, the higher the liquid is attracted by it. This is called capillary attraction.

When a capillary tube is curved below the elevation which its attractive power is overcome by gravitation liquid will be slowly carried off by its gravitation fresh atoms continue rising to supply its place fibres of asbestus, flax, cotton, or hemp loosely a bundle of capillary tubes; and when the up permitted to lay over the lip of a vessel containing into which the lower end is immersed, the liquid will eventually be conveyed out of the vessel.

Article 12. On the Gaseous State.

If the liquid state of matter may be referred to the agency of caloric, its agency in supporting the gaseous state is still more remarkable. In what precise manner caloric exerts its agency to expand solid bodies into rare elastic gasses, is not known; but it appears, as will hereafter be shewn, that almost every solid, when sufficiently heated, is capable of being converted into a gas.

Supposing, hypothetically, that matter consists of solid atoms, possessing mutually attractive and repulsive poles, and that when they attain a certain arrangement, approximation; and balance of the attractive and repulsive forces, they produce a cohesive solid: it would appear, that the application of caloric increases their repulsive force, the atoms are removed further asunder, the cohesive solidity is gradually lessened, and at last destroyed. The body now, according to its properties, remains, within a certain temperature, and under a certain pressure, in the state of a liquid, in which, although the peculiar polar arrangement and cohesion is destroyed, a certain degree of cohesion remains; or it assumes a strong attraction for a large portion of caloric, and, combining with it, expands and assumes the state of a gas. Whatever may be the real cause and support of this elastic gaseous state, the texture, if it may so be called, of gasses is perfectly uniform. No porosity, no want of continuity, is perceptible. Hydrogen, the lightest of them, is apparently as continuous in its texture as gold or platinum, the two heaviest bodies that are known. And yet the difference between them as to the quantity of gravitating matter they contain, is as twenty-seventy-five thousand to one nearly.

[redacted]pon a ball of solid matter, surrounded by seas [redacted]move about at the bottom of an ocean, or [redacted] that rises to a great height above us, [redacted]sses upon the earth, and upon us with great [redacted] are incapable of living out of it, and the phenomena we observe around us take place under this atmosphere, and its pressure, unless when they are removed by art. This atmosphere, or air, is retained by its weight or gravitation. It presses upon the general level of the earth's surface with a weight which is equal to about thirty inches of mercury, or thirty-four feet of water. As fluids press equally in all directions, it presses upon every part of

our body with a force nearly equal to fifteen pounds upon every inch of surface of our skin. Ascending from the surface of the earth, the weight and density of the atmosphere above diminishes, in a rapid proportion as it is relieved from its superincumbent weight.

	Inch. of mercury
Thus, at 1000 feet above the surface it supports	28.91
2000	27.86
3000	26.85
4000	25.87
1 mile	24.67
2	20.29
3	16.68
4	13.72
5	11.28
10	4.24
15	1.6
29	0.05

Many gasses, it has lately been discovered in the laboratory of the Royal Institution, may be condensed by great pressure into liquids. They are all of them readily condensed by chemical attraction. Oxygen and [illegible] combine in certain proportions, and are conde[nsed] water. Nitrogen, hydrogen, and oxyge[n] abundance, condensed in combinatio[n] solid animal matter.

Bodies, when in the gaseous state, having [little] attraction, have a disposition to diffuse themselves throu[gh] each other, notwithstanding any difference in their speci[fic] gravity. If a bottle full of hydrogen, for instance, be co[n]nected with another of oxygen, by means of a tube or twentieth of an inch in diameter, and a foot or more length; the bottles being placed laterally, or even with th[e] bottle of hydrogen inverted above the oxygen; after a time

the gasses will be found to be mixed, and both jars to have become explosive.

When a gas is dried, and then placed over any liquid—water for instance, it will be observed to increase a little, both in volume and weight, in consequence of a certain part of the water becoming dissolved, or diffused through it in a state of vapour.

There are different opinions whether this water is dissolved by a certain chemical attraction between it and the gas, or whether there is merely a mechanical mixture. The quantity, which varies with the temperature, does not appear to be governed by the nature of the gas, but to be limited by the law that produces the vaporization of water in a vacuum. It is called, in relation to atmospheric air, hygrometric water.

The atmosphere around us consists chiefly of two material chemical elements, that are in a permanently gaseous state, nitrogen and oxygen. With them is mixed an ever varying proportion of hygrometric vapour. These gasses appear to be merely mechanically mixed together, or at least to be held together by a very slight force.

The hygrometric vapour that is mixed in the atmosphere is ever varying in proportion, consequent upon its ever varying temperature. But there is a proportion which it never exceeds, a point of saturation: this proportion varies with the temperature. The water of the ocean, if there were not an aerial atmosphere, would form a column of vapour of such a density and pressure as to prevent further evaporation of it. The density of this watery atmosphere would be slight, and perpetually varying with the temperature. On the temperature rising, dryness would be produced, and further evaporation would follow: on the temperature falling, a part of the vapour would be precipitated, and dampness ensue. This is precisely what hap-

pens in the atmosphere now, but more slowly and modified by various circumstances.

Vapour forms from ice, whether in a vacuum or in the atmosphere, at the lowest temperature that has been examined. At 32° water produces vapour capable of supporting the weight or pressure of one-fifth of an inch of mercury. The height of the column increases in an increasing ratio, as the temperature rises, and at 212° its pressure is equal to that of the atmosphere, as may be seen in the following table, which represents the force in inches of mercury, according to the temperature of the air.

When the temperature of the air is	The force of the vapour may equal
24°	0.17 of an inch.
32°	0.20
40°	0.25
50°	0.36
55°	0.416
60°	0.516
65°	0.630
70°	0.726
75°	0.86
80°	1.01
85°	1.17
90°	1.36
95°	1.64
100°	1.86
105°	2.1
110°	2.45

So that the property of water to assume the gaseous state, increases in a rapid proportion as the temperature rises. The density of vapour, or the quantity of water, in a given volume, increases in proportion to its increasing force.

When atmospheric air is loaded with vapour to the above extent, it is saturated, and cannot retain any more, unless the temperature be raised.

Air, then, of a given temperature, is said to be dry,

when the quantity of vapour present in it is far short of saturation. The north polar winds, as they advance southward, and assume the character of north-east, and easterly winds, become a little elevated in temperature, and very dry. Hygrometric water escapes into them from every moist surface. They produce external dryness upon the human skin; and, from a cause hereafter to be explained, a sensation of cold beyond their real temperature.

Hot south, or equatorial winds, on the contrary, contain a large proportion of hygrometric water. As they approach the polar regions, their temperature is lowered, and a part of their hygrometric water is precipitated, producing warm damp air, mist, or small rain. A similar damp misty state of the air is frequently produced by the intermixture of different currents of air, of different temperatures, when a quantity of hygrometric water is generally separated; always when the currents are saturated with vapour.

The means of measuring this hygrometric state of the air is of great importance to the meteorologist; and various instruments and contrivances have been had recourse to, for the attainment of it. There are many bodies that have the property of attracting moisture from damp air, and giving it out again to dry. By adapting a scale to one of these bodies, such as a beard of barley-seed, a hair, a slip of whalebone, &c. different hygrometers have been constructed. But this property in bodies is very unsteady, and not reducible to any known standard. The simplest hygrometer, and perhaps the best, appears to be a glass bulb full of water, with a thermometer immersed in it. When cooled several degrees below the temperature of the atmosphere to be examined, on being brought into it, a condensation of water will soon be observed on the surface; this must be wiped off, repeatedly, until no further condensation appears. The thermometer in the bulb will

shew the temperature at which this ceases; and consequently the temperature at which the air would be saturated with its hygrometric water. By consulting the foregoing table the quantity of this water may be ascertained, and by comparing it with the saturating quantity proper to air of the atmospheric temperature, their difference is seen.

The mercurial barometer simply measures the weight of the atmospheric column. The weight of this column is affected by various causes, besides the formation of vapour. In this climate most of these causes act slightly, or occasionally only, while the proportion of hygrometric vapour is ever varying; and, as vapour is lighter than the air, it displaces it, in the proportion of about 10 to 16. These variations affect the barometer.

Mr. Leslie applies his differential thermometer as an hygrometer. Covering one of the bulbs with a bit of silk, and wetting it, he estimates from the rate of evaporation, the dryness of the air. But to ensure correctness, a few precautions are necessary. For the rate of evaporation involves other considerations besides the quantity of hygrometric moisture. It is variable according to temperature, to the motion of the air, to the nature, and extent of the evaporating surface.

This property of evaporating when exposed to the air is not confined to water; although the phenomenon watery evaporation is more common, from the abundance of it. It extends to a great number of bodies, both liquid and solid, and in different degrees, constituting their difference of volatility in air.

A remarkable instance of this property in mercury happened lately on board the Triumph, one of his Majesty's ships. A large quantity of this metal, which was on board, escaped from its packages, and lay for some time, loose in the hold and lower deck. The confined air of the lower part of the ship became completely saturated

with the vapour of the metal, and salivated very severely a great part of the crew, and also a number of the people who were subsequently sent to clean out the vessel.

This property is called spontaneous evaporation, and bodies are said to be more or less volatile as they evaporate in air with more or less freedom. It is by means of this property that stimulating and odorous bodies mix with the air, and produce the sensations perceived, through the medium of the organs of smell.

The physical properties of matter are usually considered as being within the province of physical philosophy, using the term in its more confined sense. They demand, however, the attention of the chemist. Not only do they perpetually interfere in his manipulations; sometimes assisting, sometimes opposing them; but the science could not arrive at its general principles, without a knowledge of what is known, of all the properties of matter, and of the agencies that affect it.

DIVISION III.

ON THE ETHEREAL CHEMICAL ELEMENTS.

Article 1. General Observations.

The various affections of heat, light, electricity, and magnetism, are always present with matter; and are most active agents in chemical actions. It will contribute, therefore, to the elucidation of our subject to explain, before proceeding further, what we know of their more general properties as chemical agents.

Of their nature we *know* nothing. They become known to us by means of their action upon matter; or upon our senses, which are material organs. Independent of that they are unknown to us. Some philosophers consider them as having no distinct existence; but as being merely properties arising out of unknown modifications of matter. Others consider them, or a part of them at least, to be a more active ethereal kind of matter. Others again seem to consider them as the common material elements in a peculiar state; which may be contrasted to solid matter in its usual state, as the state of gas is.

Light and heat, the latter more particularly, *appear*, in numerous instances, to enter into chemical combination in measured quantities; and to be given out again in the same proportion by decomposition. But their unconfinable nature; their want of gravity; their unaccountable transference, or accumulation upon various occasions; the singular affections they exert; and the surprising protean states they communicate to matter; their mutual influence

too over each other; their analogy to some of the chemical elements, and to each other in some properties, and their remarkable difference in others, do not allow any conclusion as to their nature.

It appears most logical in the present state of our knowledge, to consider them as distinct elements. Whether they are called material or not is of little consequence, since we have still to learn what matter is. It is by no means necessary that every element that exists, and is not mental, should consist of impenetrable extended gravitating atoms; which are supposed to be the chief attributes of matter.

From what can be judged of the wisdom and power of the first cause of things, it is very possible that various elements or agents were created; differing in their properties, in a certain gradation, so as thereby to be adapted to the various agencies they were called upon to fulfil; and that these agents or elements, by the various modifications arising from their respective actions on each other, produce the bodies and the phenomena around us.

Were this a correct representation of facts, a number of the elements would so far agree, by virtue of their properties of impenetrability, extension, and gravitation—for it appears that gravitation is considered as in inherent and necessary property of matter, as to be included within our notion and definition of matter; while other elements, having properties more adapted to their final intentions, may so far differ from their want of gravitation, and perhaps of impenetrability, as to be excluded, more or less completely, from our definition of matter. In such a chain of gradation the elements, caloric, light, electricity, and magnetism, seem to form a link. But we must leave this imaginative region, and examine facts.

They appear to us, generally, as distinct chemical ele-

mentary agents; the actions of which are sometimes distinct, sometimes confounded together. We can scarcely be said to know them, except from the actions and affections they produce in matter. In short, we do not know them as distinct elements, but as agents that act upon matter, and produce remarkable changes in it. They also appear, in various instances, to affect each other.

They may, provisionally, be included under the head of Ethereal Chemical Elements.

Article 2. On Electricity.

Section 1. *Common Electricity.*

It is not intended to extend our inquiry into this subject, nor indeed into any other that is considered as more properly belonging to physics, further than may appear necessary to elucidate our knowledge of the philosophy of chemistry.

We have just said that we have no direct knowledge of the elementary nature of electricity. It becomes subject to our senses through the medium of its affections with matter. Its agency appears to be general. Where matter is found, electricity appears to be present, although it is not always apparent. It appears to be a something spread or diffused through matter, that is perpetually being accumulated or excited upon it, and that has a constant tendency to spread out again into a state of equilibrium. When it is in equilibrium, it is not apparent to our senses. Every change of state or temperature, every motion or action, whether chemical or mechanical, that happens in matter, disturbs its equilibrium. Sometimes the excitements are so slight as to require the most delicate instru-

ments to detect them; at other times they are energetic, extensive, and violent; producing lightning, thunder, whirlwinds, waterspouts, tournados, and tempests.

Dr. Franklin supposed it to be a peculiar imperceptible fluid, diffused through matter; and that the phenomena called electric, are produced by the accumulation, the deficiency, or the passage of the supposed fluid.

Other philosophers have supposed that electricity is composed of two fluids; that all the phenomena are produced by the forcible separation of these fluids, and the strong mutual attraction and tendency to re-union. This is the opinion that appears to prevail most generally in France.

Our object is to trace its properties, and the phenomena to which it gives rise. In pursuing this, we cannot proceed without the use of language borrowed from some theory; nor can we compare it but with remote material resemblances. But the names should be considered as technical, the comparisons as necessarily remote, and metaphorical; and the theory they may involve as provisional only, and used for convenience. Astronomers, in describing the laws of the solar system, find it convenient to speak of the rising and setting of the sun, although they well know that the appearances they are speaking of, have nothing to do with the sun's motion; but are produced by the rotation of the earth upon its own axis.

It has long been known that, when certain bodies are rubbed together, they obtain the property of attracting light substances. Thus, a cylinder of glass, or wax, when rubbed with silk, or flannel, attracts feathers, leaf gold, dust, &c. It was in the search after the cause of this property, that the peculiar and powerful agent in question was discovered. From the accident of its being first noticed among the Greeks as a property of amber, in their language, electron, it obtained its name.

Electricity *appears* to be capable of existing, indepen-

dent of matter, and of passing freely through empty space. Hence a vacuum is said to be a good conductor of electricity.

In relation to this agency, bodies are divided into those which permit its free transmission over them, and those which do not. Hence the terms conductor, and non-conductor. At the same time, no body is, strictly speaking, a perfect conductor, nor a perfect non-conductor.

There are many bodies which do not permit its free transmission; but permit it to pass in small quantities, when in certain states of intensity. These are called imperfect conductors.

The following substances are conductors, and are arranged in the order nearly of their conducting powers. Those at the beginning of the list are said to be superior to water in conducting power, in the proportion of three millions to one, nearly. Iron is said to be superior to sea water in the proportion of 100.000 to 1.

1. Copper
2. Silver
3. Gold
4. Iron
5. Tin
6. Lead
7. Zinc
8. Platinum
9. Charcoal
10. Plumbago
11. Strong Acids
12. Soot and Lamp Black
13. Metallic Ores
14. Metallic Oxides
15. Dilute Acids
16. Saline Solutions
17. Animal Fluids
18. Sea Water
19. Pure Water
20. Ice and Snow
21. Living Vegetables
22. Living Animals
23. Flame
24. Smoke
25. Vapour
26. Salts
27. Rarefied Air
28. Dry Earths
29. Massive Minerals.

The substances following are non-conductors, arranged

nearly in the order of their non-conducting power, or the degree in which they resist the escape of the electric fluid over them.

1. Shell Lac
2. Amber
3. Resins
4. Sulphur
5. Wax
6. Asphaltum
7. Glass and transparent bodies in general, transparent mineral Crystals, and Diamonds
8. Raw Silk
9. Bleached Silk
10. Dyed Silk
11. Wool, Hair, and Feathers
12. Iry Air and Gasses
13. Dr. Paper, Parchment, ad Leather
14. Baked Woods and Dried Vegetables
15. Porcelaine
16. Marble
17. Massive non-metallic Minerals
18. Camphor
19. Caoutchouc
20. Lycopodium
21. Dry Chalk and Lime
22. Phosphorus
23. Ice below 0° Farenheit
24. Oils, the most dense of which are best
25. Alkalies, Earthy Hydrates and Oxides.

Electricity is excited upon bodies by various means. When it is excited upon a conducting body, it simultaneously escapes, unless the body be insulated; that is, surrounded by non-conductors. When it is excited upon a good non-conductor, cannot escape, and may, therefore, be accumulated and retained. Non-conductors are, therefore, called electrics.

It has already been observed, that scarcely an action or a movement can take place, without disturbing the electric equilibrium.

1. It may be excited by the mere contact of two bodies. When two plates of glass are applied in contact and separated, the respective surfaces become feebly electric.

When two plates of metal are insulated by means of glass or wax handles, and then brought into contact, they are both, on separation, rendered feebly electric.

2. When two plates of different temperatures, one of them being previously heated or cooled, are brought into contact and separated, the excitement that is produced is greater.

3. When the insulated plates are composed of different metals, the excitement is still greater.

4. During fusion, electricity is excited; and also

5. During the process of freezing or congelation.

6. It is excited also during the conversion of solids, and liquids, into gasses; and also

7. When gasses are condensed into solids and liquids.

When electricity is artificially produced by these means, it is generally upon so small a scale as to be traced by the assistance of delicate electroscopes only. But in the grand laboratory of nature, the effects thus produced are striking, and important. For instance, the atmospheric air, when dry, is a good non-conductor; evaporation is constantly going on from the whole surface of the earth; and in a still greater degree from the ocean. The water thus raised in vapour is constantly falling again in rain. During these changes, electricity is abundantly excited. Changes of temperature also are perpetually occurring in different parts of the earth, the atmosphere, and the clouds moving through it. From the action of these, and of other existing causes, the electricity of the atmosphere is always more or less disturbed.

8. Electricity is excited by chemical action, also

9. By friction, and

10. By induction.

When two non-conducting bodies are rubbed together, electricity is freely excited, and may be conveniently and readily obtained, and rendered the subject of experiment

The common electrical machine is adapted to this property. It is composed of two non-conducting rubbers. A glass circular plate, or a cylinder, is made to revolve upon its axis, and to rub against a cushion of silk. A cylinder is the most convenient, that the cushion may be insulated in connexion with a hollow metallic cylinder, upon a glass support. A similar metallic cylinder, insulated in the same manner, is placed on the opposite side of the glass, furnished with a row of points to draw off the electricity and retain it, as it is excited on the glass. These two metallic cylinders are called the positive and negative prime conductors.

When any part of a glass cylinder is rubbed with silk or flannel, electricity is excited in the part rubbed. As the glass is a non-conductor, the electricity is retained upon the part where it is excited. It cannot spread over the surface to any other part. But if a metallic body be adjoining, or placed at a very small distance, it acts as a conductor; the electricity readily passes on to it and escapes, unless the metallic conductor be insulated. The body on which the electricity is thus produced, or collected, is said to be excited. All electrically excited surfaces attract light bodies that are brought within a certain distance.

When two feathers, or two pith balls, suspended from silken threads, are brought near to a glass cylinder excited by silk, they are attracted by it; and after a moment's contact, they are repelled. If the balls be now brought near together, they repel each other.

If two other pith balls are brought into contact with the silk rubber, they are attracted for a moment, and then repelled. These balls also repel each other. When the silk, or the balls electrified from it, are brought near to the glass, or to the balls electrified from it, a mutual attraction takes place.

From these experiments it appears, that the electricities of the silk and of the glass, are of different kinds. That bodies differently electrified attract each other; and that bodies similarly electrified repel each other.

According to the theory of Dr. Franklin, electricity is a subtle fluid that pervades all matter, and may be drawn from any body, and accumulated upon another. When glass and silk are rubbed together, a part of the electricity that was in the silk, is supposed to leave it, and pass on to the glass; whence it may be accumulated upon the prime conductor. The tendency to return to its natural equilibrium, and the resistance offered to its passage by imperfect, or non-conductors, produce the attraction, and repulsion we observe. The electricity excited upon the glass is, therefore, called positive electricity; and that of the silk negative electricity.

According to the French theory, electricity is composed of two fluids, that, when united, are in a state of quiescence; when disunited, are in a state of excitement; each kind producing its peculiar phenomena, and having a strong tendency to re-union. The positive electricity they call vitreous, because it is that which is generally excited upon glass: the negative they call resinous, because it is excited by rubbing resin; it is also excited upon sealing-wax, and shell lac. Neither of these theories is adequate to the explanation of all the phenomena of this singular agency. But either of them is sufficiently applicable to be used provisionally, for the assistance of the mind in connecting together a great number of phenomena, that are the production of the same agency.

When the electrical cylinder is made to revolve, the friction against the rubber produces a peculiar crackling noise; and on approaching the hand to the cylinder, sparks pass between them, with a snapping sound. The prime conductor that is connected with the rubber, if insulated,

becomes negatively electrified; and the conductor that is connected with the glass cylinder, becomes positively electrified.

These two states of positive and negative electricity are always coincident. When one body is rendered positively electrical, the other is always rendered negative. When glass is rubbed with flannel, the glass is rendered positively electrical, the flannel negatively. When, on the contrary, resin or sealing-wax is rubbed with flannel, the wax or resin becomes negative, and the flannel positive.

The quantity of excitement thus produced in the two bodies, is always equal, and each is just sufficient to neutralize the other.

All electrified bodies, therefore, are either electro-positive, or electro-negative; but it is a relative property. As we have seen, with respect to flannel, a body that becomes electro-positive in one case, may become electro-negative in another. If two pieces of glass are rubbed together, one will become negative, and the other positive.

Certain crystals, when their electricity is excited by heat, assume differently electrical states at the opposite ends of the same crystal. Thus the tourmaline, a prismatic [illegible] with dissimilar terminations, when heated in boiling water [illegible], when examined by a delicate electroscope, exhibit different electricities at its opposite extremities. The end which terminates in a six-sided pyramid, will be electrified positively. The other end, which terminates in three sides, will be negative. As the crystal cools, a change takes place, and the electricities are reversed.

There are certain bodies, which are usually considered as imperfect conductors, that are capable of transmitting one kind of electricity only. Dried soap, or phosphorus flame, when connected with the two poles of the battery and with the earth, transmit negative electricity only.

Hydrogen on the contrary, wax, and oil, transmit positive electricity only.

These unipolar bodies are non-conductors of either the positive or negative electricity; and very imperfect conductors respectively of the opposite. And are, therefore, usually confounded with non-conductors.

The bodies arranged in the following list are all positive when rubbed with those placed below them in the series, and negative when rubbed with those above.

1. Whatever is rubbed upon the skin of a living cat renders the fur positive, and of course becomes negative itself.
2. Polished Glass.
3. Woollens and Worsteds.
4. Feathers.
5. Dry Wood.
6. Paper.
7. Silk.
8. Lac or Sealing-wax and Resins.
9. Roughened Glass.

Sulphur is rendered positive by friction with c... tal, lead excepted; and negative by friction w... other body. White silk becomes positive wh... with black silk, with black cloth, or with ...als; and ...ne-gative when rubbed with paper, hair, or ...e hand. Wool...en cloth is positive with zinc and bismuth; slightly so wi...th silver, copper, lead, and polished iron. It is negati...ve with platina, gold, tin, and antimony. When two simil...ar ribbands are electrified, by drawing one of them lengthwa...ys across the other, that w...n has been rubbed through ...ts whole length becomes ...itively electrified, and the oth...r in consequence nega...ely. Dry air impelled upon gl...s electrifies the glass p...sitively.

When two bodies—the two conductors of the machine for instance—are in opposite electrical states, they attract

each other; and on a communication with a conductor being made between them, a spark is perceived, and the electricity of both disappears. When the communication is made by a conductor terminating in a blunt surface, the electricity forces its way, with a certain intensity, through the intervening plate of air, before the ball or blunt surface of the conductor comes into contact, producing thereby a bright spark, and a loud snap, which is increased in proportion to the intensity. Pointed conductors permit the electricity to pass through a greater intervening distance of air, but silently and gradually, as they approach the excited body.

When the two conductors of the machine are insulated, the electricity is excited to a limited extent only. After the cylinder has revolved for a certain time, no further excitement follows. But if a chain, or wire, form a communication between the rubber, or its negative conductor and the earth, the excitement may be continued for any length of time.

The atmospheric air, especially when damp, is an imperfect non-conductor. The particles of air next the machine become electrified, and being repelled, other particles approach to be repelled in succession. Thus a current is formed all around an electrified body, which carries off the electricity; and is more rapid in its action, the higher the excitement is. The drier the air is, the more perfect it is as a non-conductor; the damper it is, the more imperfect. When the air is very damp, being overcharged with hygrometric water, it carries off the electricity so fast, that it is difficult to keep the machine in a state of excitement.

Increasing the density of the air increases its non-conducting property. Rarefying air, on the contrary, renders it a better conductor.

Through an air-pump vacuum, electricity passes freely with a faint light: through a torricellian vacuum it passes

more freely. The light becomes weaker as the conducting medium becomes more free. The colour of it varies with the medium through which it passes. In passing through rarefied atmospheric air, it loses its brightness, and becomes of a dull reddish colour. In passing through carbonic acid it is blue. Through ammoniacal gas it is red. The vapour of ether produces a deep blue.

The sphere of electric attraction, and repulsion, extends to a certain distance beyond the excited surface; increasing as the excitement increases, forming an electric atmosphere round the excited body.

Any part of the skin—the back of the hand for instance—when it approaches the prime conductor, feels a peculiar titillating sensation. It exerts its influence also through air, glass, or any non-conducting substance, although the electricity itself cannot escape.

Metallic bodies that are pointed, permit the passage of electricity at a greater distance than obtuse bodies do. When positive electricity is drawn off by means of a point, a star of light appears upon the point. When negative electricity passes off, a pencil of rays is seen.

When a metallic ball, whether hollow or solid, is insulated and charged, the whole of the electric influence appears to be confined to the surface. If a solid metallic ball be insulated and charged, and then two hemispheres of tin-plate, which fit it closely, and are furnished with insulating handles, be applied over it, and then suddenly and simultaneously removed, they will carry away the whole nearly, of the excited electricity.

The communication of electricity from an excited body *to another in an opposite state*, appears to be instantaneous. *Neither can it be discovered* in which direction the electricity *passes. It is probable* that there is no actual passage; but that the equilibrium is restored by means of a propulsion, similar to that which happens, when one or more

balls are forced into a long tube that is already filled with balls, and open at both ends. Whatever number is forced in at one end, an equal number must be forced out at the other, and with the same degree of force or violence.

These electric attractions and repulsions are oftentimes demonstrated very beautifully in the heavens. The clouds are sometime similarly electrified, sometimes oppositely. At times, therefore, they repel, and at others attract each other; and from their loose texture, are frequently drawn or repelled into a thousand fantastic shapes. At times they are attracted by the lofty summits of mountains, at others repelled by them.

Frequently, in passing over metallic veins, they are attracted towards the earth by them. Sometimes a cloud, very strongly electrified, is attracted by a body of water; and in its turn, attracts and raises a column of the water. As soon as the excited electricity is discharged, a general repulsion ensues; and the water is scattered with violence. In extensive deserts, sand may be attracted in the same manner.

When to an insulated prime conductor, which is charged, an uninsulated conductor is approached to a certain distance within its atmosphere, leaving a thin plate of air, glass, or any non-conductor interposed; so as not to allow an electrical discharge, the uninsulated conductor becomes electrified in an opposite state to the prime conductor. If the prime conductor be electrified positive, the uninsulated conductor becomes negative. The contrary if the prime conductor be negative. This state remains as long as the conductors remain in their situation, and the excitement is kept up. It ceases on separating the conductors. This phenomenon electricians call electricity by induction.

In receiving the common electric spark by a ball, the knuckle, or any blunt conducting surface, induction is first produced, as the body approaches the prime conductor.

The intermediate layer of air becomes a charged non-conductor, as a plate of glass would do; but as the body approaches, the force of the attraction increases, and, at last, overpowers the resistance of the air; the electricity forces its way, with a degree of violence, a sound, and a spark proportionate to its quantity and intensity.

When we interpose an insulated conductor, or any number of insulated conductors, between the prime and the uninsulated conductors; and place them in succession at proper distances: the uninsulated conductor being placed last; on exciting the prime conductor, all the other conductors become electrified by induction. The second from the prime conductor; the third from the second; and so on.

Suppose the prime conductor to be electrified positively, the nearer end of the second conductor is negative, the middle neutral or unexcited, and the remoter end positive. A corresponding change is produced upon all the conductors, except the last, or uninsulated conductor; which is wholly negative. The intensity of the electric excitement is the same throughout. This state of induction, as existing in the respective conductors, is best seen by furnishing each conductor with a pair of pith balls, placed in the middle, and other pairs at each extremity. The respective attractions and repulsions are then seen in an instant.

If by increasing the excitement in the prime conductor, the intensity is so far increased as to extend the striking distance to the second conductor, sparks pass between all the conductors, and the electricity is restored.

Supposing electricity to be a simple element; it would appear that the influence or atmosphere of the positive prime conductor, has the property of forcing the whole of the electricity of the adjoining conductor to its remotest end; and thus rendering the nether end negative, and the remote end positive. The second conductor in the same

manner affects the third; and the third affects the fourth; and so on through the whole series to the last conductor; which must not be insulated, and which discharges its positive agency to the earth.

In the same manner, when a cloud that is highly electrified approaches to a body connected with the earth; the latter body becomes oppositely electrified by induction, and attracts the electricity of the approaching cloud with increasing force, until it come within the striking distance.

When one surface of a plate of glass, or, as it is more convenient to handle, of a glass jar, is applied to a positive prime conductor, while the opposite side is not insulated; the side in contact with the conductor becomes electrified positively, and the uninsulated side is rendered negative by induction. The electricity cannot pass through the glass, which is a powerful non-conductor, nor along the surface over its edges; but yet its influence renders the reverse side [illegible]positely electrical. If the jar be now insulated, by plac[illegible]upon a glass stand, it will be found to have both its [illegible]s highly charged with opposite electricities; nor can [illegible] them be discharged, unless it communicate with [illegible] by means of a conductor. But on such a com[illegible]n being made, a smart shock is produced, and the e[illegible] is restored. When the human body is made the co[illegible]g medium, by placing a hand in contact with each surface, a shock, which is proportionate to the intensity of the charge, is felt in the intervening joints, and across the chest. The [illegible] charge from a very large jar, or from a battery of small jars, is so powerful, as to be dangerous.

This is called the Leyden Jar, its singular properties having been first discovered at Leyden.

It is requisite to cover each surface of the glass to within about an inch of the edge, with a thin coat of metallic foil,

which may serve for a communication between the different parts of the surface, and the conducting rod.

When both sides of the Leyden jar are insulated it cannot be charged. It appears as if while one side of the jar is charging with positive electricity, an equal portion of the same electricity is forced off from the opposite surface; leaving it negatively excited. But if one side of the jar be connected with the negative side of the machine, and the other with the positive, the jar may be charged from its own electricity. Two insulated jars may be mutually charged from each other, in the same manner; mutual communications being made between the different surfaces. A jar may be silently discharged, by connecting the positive surface with the negative side of the revolving machine; and the negative with the positive side. By continuing the revolutions of the machine, they may, of course, be charged with the opposite electricity.

Four, six, or any number of insulated jars may be pla[illegible] in a series; the inside of the first jar being in contac[illegible] the prime conductor; the inside of the second in [illegible] with the outside of the first; the inside of the th[illegible] the outside of the second; and so on through the [illegible] the series of jars to the last, the outside of w[illegible] communicate with the earth. On charging the [illegible]n-ductor with either positive, or negative electric[illegible] in-sides of all the jars will be charged, by induction, with the same electricity; and the outsides consequently with the opposite. They may all be discharged at once, by a conducting rod, that connects the inside of the first with the outside of the last; or they may be discharged individually.

In discharging the Leyden jar, as in discharging other excited bodies, however far the circle of communication may be extended, the equilibrium is restored to both surfaces instantaneously. The circle has been extended, by

carrying the wires over the river Thames and back. It has been carried the space of four miles round Blackheath. In both cases the communication was instantaneous.

According to M. Gay Lussac, lightning moves at the rate of 1950 feet per second.

It appears from the experiments of Mr. Barlow on Galvanic electricity, that the intensity or power of electricity is diminished in a certain ratio, as the length of the wire is increased. It appears further, that the intensity continues equal along the whole extent of the wire, consequently then there is no dissipation of the agency during its course.

When a conducting substance is insulated, and placed in a state of induction, it possesses one range only of polarity; and the excited electricity is instantly restored, upon breaking the induction. When a non-conductor, consisting of a thin plate with two surfaces, is electrified by induction, there is still one range only of polarity; one positive pole, and one negative. But the non-conducting property of the glass keeps the two surfaces in their respective positive, and negative states; after the induction is broken. In other words, the glass is in the state of a charged Leyden vial.

When a thick solid crystal that is electric, as boracite, or a lump of glass is excited, its extreme poles or diagonals will assume opposite states; but the intermediate portion will often exhibit a series of two or more changes. One pole for instance, is positive, at a short distance the body is neutral, then follows a negative space, then a neutral, then a positive, and so on.

The intensity of electricity must be distinguished from its quantity.

A small prime conductor, and a large one, may be charged at the same time; and then separated. The intensity or force of attraction, or repulsion, will be equal, but the quantities will be respectively as the surfaces.

When the electricity that charges a jar, of one foot

surface, to such an intensity, that it will discharge itself through one inch of air, is transferred to a jar of two feet surface, it will discharge itself through half an inch of air. The quantity is the same, but the intensity is one-half only. Therefore, when two jars are charged with an equal quantity of electricity, the intensity is greater as the surface is less. When charged to an equal intensity, the quantity is as the surface of the glass.

In both cases, in discharging the jar, the whole of the electricity escapes; but the force of the shock is as the intensity, not as the quantity, when it passes through conductors sufficiently extensive.

When a great electric power is required, it is more convenient to increase the number of jars, than the size of them. Hence sixteen or twenty jars are often formed into a battery, that may be charged, and discharged at once. The intensity, and quantity, are then increased in equal proportions.

When a powerful battery is discharged through a sufficiently large conductor, or discharging rod; before the ball of the rod can come into contact with the battery, it becomes in a state of induction; when it has approached to the striking distance, the electricity passes in an instant, with a loud sound; and a brilliant spark of light passes between the battery and the conducting knob; but through the conductor it passes quietly and imperceptibly.

But when any part of the conducting circuit is interrupted, whether by the introduction of a perfect conductor which is too small; whether by an imperfect conductor, so that the electricity has not a free passage, it either will not pass, or it will force its way through the interrupted part with great violence, and the production of light and heat. Thus, the interruption of the circuit may be by a wire that is too small, by a thin plate of glass, a quantity of paper, of water, or of air. If the electricity be suffi-

ciently strong to overpower the resistance, a violent expansion takes place at the point of interruption; and the electricity forces its way, breaking down, melting, or overturning whatever opposes its course; producing a heat which is superior to that of our hottest furnaces. The heat thus produced is sometimes so great as to melt, and evaporate metallic wires. Even gold, that withstands the heat of a glass-house furnace for months together, burns with flame, and evaporates in smoke.

Attempts have been made to trace the direction in which the electricity passes between the two surfaces, to restore the equilibrium; but the attempts have been in vain. The course it has passed through is oftentimes marked clearly enough by its ravages; but no distinct marks are left which show in what direction it moved. Large quantities of electricity are frequently discharged during tempests, between the earth and the clouds, with thunder and lightning; forcing its way through inadequate or imperfect conductors; often dispersing them in all directions, with repulsive violence; but whether its passage is upward or downward, no trace is left to shew.

The electric charge of a powerful battery will force its way through a quire of paper; which is a good non-conductor. It always makes a hole for its passage, sometimes two holes. But the burrs or indentations do not mark the direction of its passage, as might be expected, if it were a fluid, as it is often called. The edges of the holes are turned outwards in both directions from the middle of the paper, as if the force producing them had burst violently from that part.

There is an instrument that is very useful in examining the properties of electricity, which is called an electrophorus. Upon a metallic plate is placed a plate of resin, or of a mixture of resin and lac, about half an inch thick; the bottom of which should be covered with a coat of tin-

foil, extending to a short distance from the edge. Upon the resin is to be placed another plate of metal, which is rather smaller than the resin, and furnished with an insulating handle.

When the resin is rubbed with dry wool or fur, it becomes negatively electrified. On applying the metallic plate, and raising it by its handle, it is found very feebly negatively electrified. If it be applied again, touched by the finger, and then raised; it gives a spark of positive electricity. This latter operation may be repeated a number of times, without a fresh excitation of the resin.

In this instrument the irregularities on the surface of the resin, insulate the upper metallic plate; and it becomes positively electrified by induction, on touching it for a moment with the finger, or any other conductor, to uninsulate it. On removing it, the induction is broken, and it gives off positive electricity.

It appears from this experiment, that a body, while under the influence of induction, has an increased capacity for electricity; and that, on the induction being broken, this increased capacity ceases. On touching the plate with the finger, while it is under induction, it abstracts a quantity of positive electricity that is equal to its increased capacity; and this precise quantity is again given out, with a spark, on touching it again, after the induction is broken.

A further proof that bodies, while under induction, have an increased capacity for electricity, is obtained by connecting an insulated brass plate, with a delicate gold-leaf electroscope. When a similar plate, not insulated, is brought so near as to leave a thin plate of air between them, it will be feebly electrified, by induced electricity. The gold leaves will be quiescent nearly. Upon suddenly withdrawing the uninsulated plate, the gold leaves will diverge. But, upon bringing the uninsulated plate again

into a state of induction, the gold leaves will collapse: the electrical intensity being again diminished, in consequence of the increased capacity, produced by induction.

Section 2. *Voltaic Electricity.*

Another mode of obtaining electricity, under different circumstances, and in great abundance, has more recently been discovered. On account of its novelty, the singularity of the phenomena attending it, of its convenient adaptation, and powerful agency over the laws of chemical attraction, it has obtained particular attention.

It has been observed, that when two plates of two metals, of zinc, for instance, and copper, are brought into contact, and separated, electricity is excited; although it is small in quantity, and feeble in intensity. It was accidentally discovered, that when a limb of a frog was laid across the ends of two wires, of different metals, which were in contact at the other ends, so as to form a circle, it became violently convulsed. Further attention to this phenomenon shews, that the nerves of animals recently dead, are powerfully stimulated when connected as part of an electric circle with two metals; or with any other two bodies that are capable by their contact of exciting electricity.

When one end of a rod of zinc is placed above the tongue, and one end of a rod of silver, or copper, below it; on bringing the opposite ends into contact, a sensation or taste is perceived.

When the metals are applied to the two extremities of the limb of a living or recently dead animal, so as to include the course of a principal nerve, violent contractions of the limb are produced. Hence the origin of galvanism.

Although electricity, however excited, has the same

property when applied in a similar manner; yet these phenomena led M. Galvani, the discoverer, into erroneous physiological conclusions.

M. Volta, another Italian philosopher, in pursuing his inquiries into the cause of these phenomena, was induced to try whether several of these circles could not be united as to produce a joint, or accumulated action. The trial succeeded. A new and most powerful modification of electricity was discovered, possessing chemical agencies which were unknown before. A road was thus opened to chemical elucidations, that surprised every one; and has formed an important era in chemical philosophy.

The galvanic circle is formed generally of three different bodies. Various arrangements may be employed. Two perfect conductors, and one imperfect, answer best; but the circle may consist of one perfect, and two imperfect conductors. The two perfect conductors are consequently metals; and the more they differ in relation to their attractions for oxygen, the more powerfully they act. For instance, zinc has a very strong attraction for oxygen, copper a much weaker, and silver a weaker still. A good galvanic circle is produced by using zinc and silver, or copper and silver; but if zinc and silver were used, the combination would be more powerful. In all cases the most oxidable metal assumes the positive pole, and the least oxidable the negative.

The most perfect and, at the same time, economical for use, consists of a plate of zinc and another of copper, in contact at one end, and connected at the other through the medium of water, or of some imperfect conductor containing water.

The voltaic pile, or battery, consists of a number of these series, placed and connected together, in uniform succession.

The first pile was formed of small disks of zinc, and

copper or silver, and of wet flannel; repeated series of which were regularly arranged in contact. This arrangement was improved upon by fixing zinc and copper square plates, soldered together at short distances, in a trough of baked and varnished wood; the intermediate cells, thus formed, being filled with water, or an acid solution. In both cases, a wire connected with the extreme plate of zinc at one end, and another connected with the extreme plate of copper at the other; when brought together, form a complete voltaic circle.

It is by reducing bodies, that are to be subjected to experiment, to the state of imperfect conductors, that they may be submitted to the chemical agency of the voltaic battery.

Another mode of arrangement, and, for some purposes, a better, is to provide earthen or baked and varnished wood troughs, divided by the same material, into distinct cells. In this arrangement the metallic plates are distinct. The copper and zinc of the first series are connected, at the upper ends, by a metallic strap; while the lower ends are immersed separately into the first and second cells. The zinc being immersed in the first cell, the copper is immersed in the second. Of the second series, the zinc plate is immersed in the second cell, at such a distance as not to touch the copper of the first series, while the copper of the second series is immersed in the third cell. The same attention and order is observed in placing the third, and all the remaining series, and also in connecting the different troughs together. It is convenient to fasten together as many of the series as belong to each trough, for the convenience of removing them at once. But the connecting handle must be a perfect non-conductor. The series may be repeated to any extent.

A number of series thus arranged form a voltaic circle, or battery, possessing to a certain extent, the accumulated

power of all the series. The zinc extremity of the battery constitutes the positive pole, and the extremity ending in a copper plate the negative.

The great battery of the Royal Institution was upon this construction. It consisted of a series of 2000 double plates, each plate of which being four inches square, exposed thirty-two inches of surface to the action of the liquid employed.

Its intensity seemed to increase with great regularity to the extent of about 500 or 600 series. Beyond that number, the power did not seem to increase in proportion to the number, but in a constantly diminishing ratio. Upon some occasions, when the whole of the 2000 series was employed, the power did not appear to be greater than when half the number was employed. It appeared that neither the respective series, nor the whole battery, were sufficiently insulated to support the intensity.

In the single galvanic circle, the two metals in contact, excite each other; the one becoming positive, the other negative. On uniting the remoter ends, by the medium of an imperfect conductor, a current of electricity appears to be established, and to be continually passing round the circle: it passes quietly and unobserved through perfect conductors; but, according to its intensity, shews itself in passing through interrupted, or imperfect conductors.

In the voltaic battery the individual circles are not completed; the excited electricity of each series passes through the remainder to the two general poles, where the positive and negative energies of all the series are accumulated; and, by means of their conducting wires, may be passed through any body that is made a part of the general circle.

When the circle is interrupted, the two poles of the battery are highly excited; while the middle part shews no marks of excitement. But when the poles are united by a perfect conductor, a regular circulation appears to be

going on; and the excitement appears to be equally spread over the whole circle.

It appears that in the voltaic battery, a comparatively large quantity of electricity may be excited; but to a low intensity only. When the circle is completed, the production of electricity appears to go on as the intensity can discharge it; but when the circle is interrupted, the production of electricity is also interrupted: it cannot be accumulated upon conductors, as it can when excited by friction.

The intensity of the voltaic battery increases with the number of the series, without any relation to the size of the plates. The intensity is the same, whether the surface of the plates be one inch square, or three feet; so long as the conducting surface is the same, and less than the exciting surface, the quantity of electricity which can be conducted is as the intensity. Bad or imperfect conductors can carry off a small quantity only, in proportion to their surface. To increase the quantity transmitted, the intensity must be increased, and good conductors employed. But the quantity of electricity that is obtained, and consequently, the power of the battery, in such experiments as require quantity rather than intensity, depends upon the extended surface of the plates.

In acting upon imperfect conductors, a certain intensity is necessary to force a passage. In acting upon perfect conductors, a large quantity is necessary to produce any chemical effect, or to produce heat. The heating power is then increased by increasing the size of the plates; or by lessening the diameter or size of the metallic wire or body to be heated, rather than by increasing the intensity only.

When the plates are of a given size, the increasing power in producing the ignition of metallic wires, appears to be as the number of series. The increasing power of the battery in producing chemical decomposition, appears to

be nearly as the square of the number of series, or rather as the square of the increased intensity they produce.

When the number of the series is fixed, the power of producing ignition of metallic wire, or of decomposing sulphuric acid, or strong saline solutions; increases in a ratio which appears to be considerably greater than the square of the increasing surface. But so many sources of error exist, and the results are in consequence so contradictory, when great numbers or large surfaces are employed; that it is not easy to arrive at any conclusion fit to be depended on.

The disposition of bodies to assume the positive or negative states, varies with their relations to each other.

In the following list, the bodies are placed in the order of their disposition for assuming the positive state. They are positive with all that follow, and negative with all that precede them.

Zinc	Silver
Iron	Gold
Tin	Platinum
Lead	Charcoal
Copper	

The excitement produced is the strongest between those bodies that differ most in their electric disposition.

Water is the most convenient imperfect conductor that can be used in forming a voltaic battery. The action is increased by the addition of neutral salts. It is much more strengthened by the addition of acids; but it is remarkable, that any imperfect conductor that does not contain water, produces a very feeble circle or battery.

Chemical action between the different parts of each circle, increases very powerfully, both the quantity and intensity of the electricity evolved; and water is readily decomposed by double attraction in all cases of chemical action between metals and their solvents. Consequently,

it powerfully increases these chemical actions, and in many cases they do not go on without it.

De Luc's column is formed of a numerous series of thin plates of zinc and silvered paper, inclosed in a glass cylinder, rendered air tight by brass caps. Two of these columns placed in contact at one end, and separated at the other sufficiently to allow a small bell to vibrate between the opposite poles, have kept the bell vibrating for three months successively.

Some chemical philosophers have supposed that the galvanic electricity is the product of chemical action. When chemical action is going on between the elements of the respective series, it is, no doubt, remarkably increased; but in De Luc's column, it is difficult to suppose the presence of chemical agency. Besides, electricity may be excited by friction, for any length of time, in situations where chemical action cannot take place. In hydrogen gas for instance, in carbonic acid, or in any other single gas.

The addition of from one-sixteenth to one-twentieth part or more of nitric, muriatic, or sulphuric acid, or of a mixture of them, to the water, increases the electric energy to a great extent. The mixture may be advantageously varied to suit various experiments. The action of the acid upon the zinc, or positive pole, is much increased during the action of the battery, or when the circuit is complete. The action upon the negative or copper pole, during the same time, is suspended. Upon this property is founded the plan of Sir Humphry Davy, for preserving the copper sheathing of ships from the action of sea water.

Voltaic arrangements may be formed by means of one perfect and two imperfect conductors; of a metal for instance, sulphuret of potassa, and an acid solution; or, a metal, solution of potassa or soda, and an acid solution. But the power of these arrangements is low.

The metals having the strongest attractions for oxygen

assume the positive pole, when the fluid is decomposed, and affords oxygen to it; but when the fluid yields sulphur to the metals, the metal that has the strongest attraction for sulphur assumes the positive pole. Thus, in a certain series of iron, copper, and acid, the iron is positive. In a series of iron, copper, and solution of sulphur with potash, the copper is positive.

In combinations with one metal, an acid, and a solution of sulphur, or of an alkali; that extremity of the metal which is applied to the sulphur, or alkali, is positive; and that applied to the acid, negative.

The intensity and strength of the circle is very much increased by carrying the copper plate round both sides of the zinc plate. In this manner a galvanic circle has been formed of a thimble, so powerful, as to be capable of igniting a fine platinum wire.

Generally the relative power of the voltaic battery in its adaptation to particular purposes, depends upon the electro-positive and electro-negative powers of the respective metals, the number of the series, the size of the plates, the proportion between the surfaces of the zinc and copper, and the conducting and chemical power of the liquid imperfect conductor.

Bodies that are intended to be submitted to the action of the voltaic circle, or battery, must be rendered imperfect conductors, and placed in the circle between the connecting wires from the two poles of the battery.

In this point of view imperfect conductors are of two kinds, and produce different phenomena.

1. Metallic wires, or charcoal, which are good conductors, may be reduced in size until they are too small to transmit the whole quantity of electricity freely. The agency then forces its way with great violence, igniting, fusing, or even evaporating the conducting wires.

2. Conductors that are imperfect, independent of quan-

tity; as water, oxides, acids, and numerous other bodies It is in passing electricity through these, that its powerful chemical agency is more particularly demonstrated.

In producing intense heat, and fusing the first class of imperfect conductors, a large quantity of electricity is required, but great intensity is not necessary.

One of the largest batteries that has been constructed consisted of twenty series of double plates, each plate being six feet long, and about two feet eight inches broad. The power of this battery in burning metals and charcoal, was said to be superior to that of the great battery of the Royal Institution; but the intensity of it was not greater than that of twenty double plates one inch square.

In decomposing good imperfect conductors, such as sulphuric acid, or strong saline solutions, large plates act most powerfully. When two cones of charcoal are attached to the ends of the positive and negative conducting wires of a powerful battery, and brought near to each other, a most brilliant dazzling light appears. As the intervening air becomes heated, its conducting power increases, and enables it to conduct the electricity for the space of several inches, as the charcoal points are gradually separated; a most brilliant arc of light being maintained through the space between them. When 1000 of the series were in action at the Royal Institution, this arc extended to four or five inches; it might be supported for a length of time, and the light was too brilliant for the eye to bear without pain. The heat was more intense than that of the strongest blast furnace.

The most refractory of the metals melt like wax, when placed in the circle of a strong voltaic battery. Gold and platinum burn freely and evaporate into smoke. Platinum wire of considerable diameter is kept at a red, or even at a white heat, through several feet, for any length of time. The above-mentioned battery of large plates is said to have

produced a light superior to the sun in splendour, and to have kept eight feet of stout platinum at a red heat for some time. Pure lime, magnesia, silex, bodies previously considered to be infusible, are instantly melted; diamond, plumbago, and charcoal, may be evaporated.

In an air pump vacuum, the connecting distance between the wires or charcoal increases considerably. The arc of light from five hundred four-inch plates, that are in full action, may be extended six or seven inches; attended with a most beautiful purple colour, and brilliant coruscations.

Electricity, in all cases, passes silently through metals, until they are reduced to too small a size to afford a free passage to the quantity that is excited; therefore, the best metallic conductors are most difficult to heat Platinum being the worst of metallic conductors, is most easily heated. A Leyden jar of any size, or a large battery of jars, may be charged from a voltaic battery by a single touch. The charge is of the same intensity as the voltaic battery. It cannot be accumulated nor excited to a greater intensity, as it can when charged with electricity excited by friction.

When the human body is made a part of the discharging medium of the voltaic circle, the sensation or shock is slight, and proportioned to the intensity, not to the quantity. The passage and the effects of electricity, in relation to the second sort of non-conductors, varies with their respective conducting power. But generally speaking, the intensity excited by the battery is of more consequence than the quantity. The quantity excited by small plates appears to be as much as, under the existing intensity; imperfect conductors, of the second sort, can transmit; while better conductors can transmit a larger quantity, under the same intensity.

Suppose, for example, that sixty or one hundred series of plates, of four or six inches square, are employed. On completing the circle with the hands, a slight sensation is

felt. On making a second circle through a portion of water, decomposition takes place in it. On adding a third circle of metallic wire, fine wires become ignited, and still finer become inflamed, and oxidated. Gold leaf, silver leaf, and other metallic foils, burn with brilliant flames.

The low intensity of the voltaic battery, and the impossibility of increasing its intensity, by any means at present known, beyond a certain point, renders it a safe instrument.

The chemical agency of electricity is not confined to the voltaic circle. All electricity is the same. It is necessary for producing its chemical agency that a certain large quantity of electricity be supplied with regularity, and at a certain low intensity, that is capable of variation in a limited degree. For this state of its production the voltaic pile is the most convenient, and is easily manageable. But electricity excited in any other way, may be managed so as to produce the same effect. The discovery of the component parts of nitric acid, was made by the late Mr. Cavendish in consequence of his effecting its decomposition, by the continued discharge of electricity through it, excited by friction from a powerful battery. Dr. Wollaston also has shewn that when two pieces of fine gold wire, reduced to one-fifteen-hundredth part of an inch, or perhaps less, are hermetically sealed in capillary tubes of glass, or wax; with their extremities exposed, and made part of a circle between the positive and negative prime conductors of a common electrical machine, water may be decomposed, and similar chemical actions produced.

From twenty to one hundred series of plates, between one and four inches square, will answer for most purposes of chemical decomposition.

When a compound body is placed in the circle between the two poles, the proximate elements of it become oppositely electrical, and are attracted to opposite poles of the battery. The electro-negative body is attracted to the

electro-positive pole, and the electro-positive body to the electro-negative pole. By this means the body is decomposed.

In all decompositions the chemical elements, oxygen, chlorine, iodine when present, are attracted to the positive pole.

All other bodies in relation to them are electro-positive, and attracted to the electro-negative pole. These electro-positive bodies are attracted to the electro-negative pole, with very different degrees of force; and, when combined among themselves, those that have the slightest attraction assume an opposite character, and are attracted by the electro-positive pole. So that perhaps there is only one body that is absolutely electro-positive, and only one absolutely electro-negative.

Water is a compound of oxygen and hydrogen. It is readily decomposed by the voltaic battery. The oxygen is attracted to the positive wire, the hydrogen to the negative. When the positive wire has an attraction for oxygen, as copper for instance, it combines with the oxygen producing oxide of copper. When gold or platinum constitutes the positive wire, the oxygen does not combine with it; but it is seen issuing from the wire in minute bubbles, while the hydrogen is seen issuing from the negative wire. By keeping the two wires immersed in the water, at a small distance asunder, and placing inverted tubes over them, the two gasses may be collected separately.

This singular phenomenon at first created great surprise. A property seemed to be demonstrated that was previously unknown. How do those elements arrive unperceived by us at the respective wires, whence they appear to issue?

When a solution of a neutral, or of a metallic salt, is placed in the circle, the alkali or metal is attracted to the negative wire, and the acid to the positive.

When an acid, sulphuric acid for instance, a compound

of sulphur and oxygen, is the object of experiment, the sulphur is attracted to the negative pole, the oxygen to the positive.

When a bar of copper is immersed into a solution of nitrous acid, a chemical action immediately commences between them. If a bar of zinc be now introduced, an action commences between it also and the acid. On bringing the upper ends of the two metals into contact, a galvanic circle is produced; the copper becomes negative, and is no longer acted upon by the acid; while the zinc, which is become positive, is acted on with additional force.

So strong are the electrical attractive forces, that the strongest chemical attractions are overpowered, acids are attracted by it through alkaline solutions, alkalies through acids, all power of combining being suspended, as was first noticed by Davy.

When three cups are placed in the course of the circle, and in the exterior cups are placed solutions of a neutral salt, of sulphate of potassa for instance, and in the middle cup a solution of nitrous, or any other acid, on completing the circle by connecting the wires to the exterior cups, and connecting the cups together by bits of wet cotton or asbestus; the sulphates of potassa in both cups will be decomposed. The sulphuric acid will gradually be all attracted into the cup that forms a part of the positive pole, and the alkali will be attracted into the cup that forms a part of the negative pole; a portion of the acid and alkali, passing through the acid in the middle cup without being affected by it.

But if either of the proximate elements should meet in the middle cup with any body with which it forms an insoluble compound, it will combine with it, and falling to the bottom of the vessel, be carried out of the electric circle. Thus, in the above case, if a solution of baryta, or lead, be placed in

the middle cup, the sulphuric acid that is passing through it will form an insoluble sulphate, which is precipitated.

So strong is the attractive force of this agency, that it disposes to decomposition, and acts upon the vessels and instruments that are employed, so as to produce anomalous appearances, that can be avoided only by caution and refined management.

To effect the decomposition of a body, it is not necessary that it be in solution. Sulphate of baryta, fluor spar, glass, all the most insoluble compounds, when powdered, moistened with water, so as to render the mass an imperfect conductor, and placed in the circle, are readily decomposed.

Many circumstances had, for some time previously to the discovery of the voltaic pile, led to a suspicion that potassa, soda, baryta, and, analogically, most of the other earths, must be compound bodies. The application of the voltaic battery readily decomposed both potassa and soda. Their bases consist of two very singular metals, combined with oxygen. Several of the earths also have been decomposed, more or less perfectly; and scarcely a doubt is left, but that all of them are composed of a metallic base, combined with oxygen.

A curious fact, which has already been mentioned, that during the time the galvanic circle is complete, the chemical action of the fluid upon the electro-negative metal is suspended; while the action upon the electro-positive metal is increased; and the further fact, shown by Dr. Wollaston's galvanic circle, made with a thin sheet, that the doubling of the electro-negative, or copper surface, doubles the power of the galvanic electricity, appears to have suggested to Sir H. Davy the application of the galvanic circle to the preservation of the copper sheathing of ships, which is powerfully acted upon and corroded by the saline matter in the water of the ocean.

Upon trial it was found, that a very small proportion of zinc or iron, both being electro-positive metals in relation to copper, were completely effectual in preserving the copper from any chemical action.

But it was found, on experiment, that marine mollusca and vegetables began to adhere to the copper, as to wood, consequent upon its poisonous property being suspended.

The application does not, therefore, become useless; it is less effective merely. A little experience will readily point out that degree of partial defence which, while it prevents the adhesion of animal or vegetable bodies, will also prevent the unnecessary waste of the metal. So that its durability may be much protracted, even if corrosion cannot, with advantage, be wholly prevented. Besides, the protecting metal may easily be so applied, as to be capable of increasing or diminishing the poisonous energy, as occasion shall require.

Article 3. Of Magnetism.

Section 1.

Magnetism very rarely appears to us in the character of a chemical agent, nor is it usually considered as such. Its use in navigation has rendered it an important subject in physics, and its properties are extensively treated of in that science.

By magnetism is meant the property that certain native iron ores have of attracting iron. The same property may be communicated to bars of steel, by certain manipulations, that produce their effect with certainty, but in a manner wholly unknown.

The earth may be considered as an enormous magnet; and, like other magnets, it attracts iron, or another magnet,

in two opposite directions only. The parts of a magnet, where these attractions act, are called its poles. The magnetic poles of the earth are supposed to lie at a depth within the earth, and at no great distance from the equatorial poles; therefore, although they are not strictly due north and south, they are usually called the north and south magnetic poles; and the same name is applied to the respective poles of all magnets.

The corresponding poles of magnets repel each other; the opposite poles attract each other. Hence it follows, that in the common compass box it is the south pole of the magnet which is attracted to the north pole of the earth.

Section 2. *Electro-Magnetism.*

A curious mutual influence has lately been discovered to exist between electricity and magnetism. It has already been seen to what an extent electricity excites heat. It has been noticed, also, that lightning has frequently destroyed the power of a magnet, at other times has reversed its poles.

It has lately been discovered by Mr. Oersted of Copenhagen, that when the electric circle is completed by a connecting wire communicating between the two poles of a battery, a magnetic agency is in action, and to appearance is passing spirally round the course of the electrified wire. When a small magnetic needle, properly suspended, is brought near the wire, its point is immediately directed east or west, according to its relative position. Suppose the electric circle to be placed with the positive pole northward, and to the right hand of the spectator, the magnetic agency then appears to pass along spirally round the electrical wire, in the same direction, approaching the spectator as it passes under the wire, and, consequently, re-

ceding as it passes over; in both cases carrying the point of the needle with it.

If a bar of hardened steel be placed in the direction of the magnetic current, it becomes a magnet. The nearer it is placed across the electrical wire, and the more powerful the electricity is, the more powerful will the magnet become.

If the electrical wire be curved spirally, and the steel bar be placed within the helix so formed, the magnet will be rendered still more powerful, and it will also be attracted with some force towards the negative extremity of the pole. If the magnet be inclosed in a glass tube the same effect is produced.

Various contrivances have been adapted to shew the magnet practically revolving round the conducting wire; and also to shew the electrical conducting wire revolving round the magnet.

The better the electrical conductor is, the more powerfully it shews the phenomenon. A silver conductor is, therefore, superior to an iron one.

Article 4. Of Light.

This beautiful object of vision, the subject of the physical science of optics, the source of painting, and of numerous delightful amusements to the perception, the imagination, and the understanding of man, is at times an agent in chemical attraction also. But it is much less an object of chemical than of mechanical science.

The great source of light to us is the sun. It is abundantly produced in combustion also, and in various other chemical actions. It is produced by the passage of electricity through imperfect or insufficient conductors. It is

emitted from all ignited bodies. It is emitted from various bodies that are not heated, and which are called phosphorescent.

Bodies which emit light are called luminous, and are distinguishable from those which reflect the light falling upon them.

The rays of light issuing from the sun proceed in straight lines, and in all directions, at the rate of about two hundred thousand miles a second. This astonishing velocity has contributed to give great plausibility to an opinion that vision is produced by undulations of some ethereal elastic medium, as sounds are produced by undulations of air, or waves by undulations of the waters of the ocean.

The rays of light are reflected by polished opaque surfaces, like bodies that are perfectly elastic, at an angle that is equal to the angle of their incidence. In passing out of one transparent body, that is more or less dense, into another, they are bent, or refracted; but pass on in the new direction in a straight line as before. When the rays fall upon the retina of the eye, they produce a picture which represents the object they are reflected from, and which appears to exist in the direction whence the rays arrive at the eye.

No light is visible that does not fall or impinge upon the retina. If we look across a cylindrical tube, through which light is passing, all lateral reflection being prevented, no light is perceptible; or, if a burning candle be placed in the middle of a large room, that is free from dust, and from the darkened walls of which no light can be reflected, although the rays from the candle extend to every part of the room, no light can be seen unless the candle be looked at. When we look across the room, in any other direction, it appears perfectly dark. In general, a beam of solar light passing before the eyes in a dark room, appears to be visi-

ble. It is rendered so by the particles of dust that float in the air intercepting some of the rays, and reflecting them to our eyes.

Bodies, in relation to light, are transparent and opaque, as is well known; but no body is perfectly transparent, the most transparent body transmits a part only of the rays that fall upon it.

When a ray of light passes obliquely from air into water or glass, it is bent, on entering the surface, and then passes on in a direction that approaches more nearly to that of a line drawn perpendicular to the surface. The more dense the new medium, the more nearly does the new line of direction approach to the perpendicular of the surface. But when the ray falls perpendicularly on the surface, it passes straight onwards.

When a ray of light passes obliquely out of a dense medium into one which is more rare, it is bent in a corresponding degree, in an opposite direction—that is, it passes on in a line more bent from the perpendicular, as the medium becomes rarer.

Thus, a beam of light passing from the air into a thick plate of polished glass, is bent towards the perpendicular as it enters; and there passes on in a straight line to the opposite surface.

When passing out of the glass into the air, it is again bent, in an equal degree in the opposite direction, and passes on in a line parallel to that in which it passed before entering the glass. Upon this properly depends that part of the science of physics called dioptrics.

Various crystals, the rhomboidal spar for instance, have the property of splitting the rays that fall upon it, and refracting the divided parts in two directions, so that an object appears double through it, or in two places.

As the rays of light coming from a body pass in straight lines, equally in all directions, it happens, consequently,

that the quantity of light falling upon a surface diminishes as the surface recedes from the body, in a proportion which is equal to the square of the increasing distance. The apparent magnitude of bodies receding from the eye, diminishes in the same proportion. Hence, when a body is viewed through a perfectly clear transparent medium, it appears equally bright, whatever may be the distance; but as the distance increases, the apparent magnitude diminishes. On this property are founded the laws of perspective.

A ray of light falling perpendicularly upon a polished opaque surface, is reflected straight back again. When it falls obliquely, it is reflected in the opposite direction, with the same degree of obliquity. The angle of reflexion is exactly equal to the angle of incidence. The consideration of its laws belongs to that branch of physics called catoptrics.

When rays, issuing from a luminous surface, are intercepted in their passage, by any body, a shadow is formed, by the absence of the rays intercepted. The appearance of the shadow will vary, as the interrupted rays are passing, in a parallel, a converging, or a diverging direction.

A convex lens, of clear polished glass, should, to understand its optical properties, be considered as a surface composed of an immense number of minute planes, that are gradually and regularly varying in direction from the central plane. When a beam of light falls upon it, each ray is refracted at a different angle, but, as the deviation is regular, all the rays are refracted, so as to meet in one point or focus. The more convex the lens is, the more the rays are bent from their former parallel direction; and the shorter the focal distance. Thus, the parallel rays that come from a distant object, and fall upon the whole surface of the lens, being bent inwards, cross each other at the focus; and form a picture of the object, which may be received by

the eye, or upon a sheet of paper. Were the glass forming the lens perfectly transparent the object would appear very much brighter and clearer than to the naked eye; for all the rays that fall upon the broad surface of the lens would pass in at the narrow pupil: but no body is perfectly transparent. A distant object nevertheless appears larger, and more distinct than it does to the naked eye; in the same proportion as the concentrating power of the lens, is superior to its dispersing power.

The properties of a concave lens are the reverse of a convex. Instead of concentrating the rays, it disperses them. Instead of approximating and magnifying objects, it removes and diminishes them.

Telescopes, microscopes, and various optical glasses, are adaptations of these properties to particular purposes.

The eye is an optical instrument, composed of lenses of different diameters and densities. They converge the rays of light that fall upon the cornea, and are transmitted through the pupil, so as to paint a picture upon the retina, of any object that is viewed. This object, indeed, is reversed, and inverted, although the mind perceives it in its natural position.

Speaking strictly and correctly, it is not the body that we see, but the rays of light that are either emitted or reflected from it. If matter were visible, there would be no darkness. When rays of light from an ignited body, from the sun for instance, or from a lamp, fall upon a body, this body, if opaque, has the property of reflecting a part of the light with peculiar modifications of its colour, and shadow. From the picture that is formed upon the retina thus coloured and shaded, and which in fact is the real object, the mind, instructed by practice, infers the existence and the nature of the body. How the perception of this picture upon the retina is conveyed to the mind is wholly unknown; except that from the retina a nerve passes into the brain, and mixes with it. If this nerve be divided or injured in

its functions, the mind has no perception of light, although the picture may be perfectly formed on the retina.

When the lens of the eye is too convex, it converges the rays to a focus before they reach the retina, and the picture is consequently confused. This produces the short-sighted eye. It is benefited by a concave glass which, by slightly diverging the parallel rays before they enter the eye, lengthens the focal distance.

When the convexity of the cornea or lens of the eye is too small; as it is sometimes from original mal-conformation, but more frequently from the cornea becoming flatter by age, the focus is thrown too far back. This evil is relieved by the use of convex spectacles.

Generally speaking, the refracting power of transparent bodies is as their density. But the bodies called inflammable have a refrangent power, which is greater than is proportional to their density.

Hydrogen gas is, in proportion to its density, the most refrangent of all bodies, and the most inflammable. The diamond is the most powerfully refrangent of any solid mineral, and owes its distinguishing beauty to that property. Water also, and essential oils, are highly refrangent in proportion to their density.

The following list shews the comparative refrangent powers of a number of bodies, the other properties of which will be noticed hereafter.

TABLE I.

Atmospheric Air - - - - - - -	1.
Carbonic Acid - - - - - - - -	1.00476
Nitrogen - - - - - - - - - -	1.034
Muriatic Acid Gas - - - - - -	1.196
Oxygen Gas - - - - - - - - -	1.862
Carburetted Hydrogen - - - - -	2.092

Ammonia	2.17
Hydrogen Gas	6.6

TABLE 2.

A Vacuum	1.
Atmospheric Air	1.00033
Water	1.336
Ether	1.358
Alkohol	1.370
Nitric Acid	1.410
Oil of Lavender	1.467
Oil of Olives	1.469
Plate Glass	from 1.500 to 1.580
Crown Glass	1.525
Rock Crystal	1.547
Flint Glass	1.583 to 1.586
Guaiacum	1.596
Carburet of Sulphur	1.680
White Sapphire	1.768
Spinell Ruby	1.812
Jargon	1.950
Phosphorus	2.224
Diamond	2.440
Chromate of Lead	2.479 to 2.926

The apparent magnitude of a body is proportionate to the space its picture occupies on the retina; or as it is called the visual angle: that is, the angle produced by straight lines coming from the extreme boundaries of the object to the eye. Experience and judgment also are necessary in estimating the true distance and size of bodies.

A very small object, when brought near to the eye, appears equal in size to a large object that is at a certain distance from it.

Bodies receding from the eye diminish in apparent magnitude, in a proportion which is as the square of the increasing distance; that is, a body which appears of a certain size at the distance of one foot, will appear only one-fourth of the size at the distance of two feet, one-ninth at three feet distance, one-sixteenth at four; and this apparent diminution will continue as the distance is increased.

A distant object, the real magnitude of which is unknown, will appear to be nearer according as the intervening mass of air is more pellucid; and as the different parts of the object appear more distinctly.

When a ray of solar light falls upon a transparent triangular prism, it is bent out of its course; and, by an unequal refraction, spread out into an oblong spectrum, consisting of seven different coloured lights, which have suffered different degrees of refraction.

Thus the spectrum consists of seven primary colours.

1. The red rays, which are the least refrangible.
2. The orange-coloured rays, which are the next in the order of refrangibility.
3. The yellow rays, which are the most illuminating.
4. The green rays.
5. The blue.
6. The indigo-coloured.
7. The violet-coloured.

The heat that passes with the light is refracted also, and unequally spread over the whole spectrum. When refracted by a prism of flint glass it generally falls in the largest proportion upon the red rays, whence it extends in a gradually decreasing proportion to the end of the spectrum. Supposing the heat of the red rays to be equal to 55, that of the green is equal to 26, and that of the violet to 16. The hottest part of the red rays is at the commencement of the spectrum. It was observed also by the late Dr. Herschel that, in the dark space which is adjoining to,

and in a line with the red rays, the heat is still greater; but subsequent experiments shew that the refraction of the caloric is affected by the composition of the prism.

When a transparent prism of water, alkohol or oil of turpentine is employed; the maximum of heat is thrown within the yellow rays. When it is formed of a solution of muriate of ammonia, or muriate of mercury; the maximum falls within the orange-coloured rays. Brown glass and white glass prisms throw the maximum of heat into the centre of the red rays. Glass prisms that contain a certain proportion of lead throw it upon the outer limit of the red rays, and a prism of flint glass throws it into the dark space beyond them. But in all cases a portion of caloric is less refracted, and consequently falls upon a space to the outer side of the red rays.

When light acts chemically upon bodies, its action is slow, and in most cases obscure. Some of the changes attributed to it appear to be due rather to the accompanying heat.

Light has the property of destroying many colours of animal and vegetable origin. It acts upon essential oils, promoting their combination with oxygen, and converting some of them eventually into resins.

The dark end of the spectrum, and more particularly a small space beyond the boundary of the violet rays, shews a tendency to disunite oxygen from some of its combinations. Oxide of bismuth, muriate and nitrate of silver, and some other white metallic combinations, in which oxygen is an ingredient, are blackened when placed in the blue or violet light of the spectrum; and still more powerfully in the dark space beyond it.

The two extremities of the spectrum have, in consequence of its chemical properties, been supposed by some chemists, to bear an analogy to the poles of the voltaic battery; the red end to the positive; the violet to the negative

pole. There is certainly a strong analogy between them: the actions of both, too, are frequently assisted and disguised by the action of the co-existing caloric. Whatever may be the cause of the de-oxygenizing power of the spectrum, it gradually increases as we advance along towards the most refrangible rays and in the unilluminated rays, directly beyond the violet rays, it is the greatest. So that the rays, which may be said to have the strongest electro-negative chemical action, have not the property of illuminating, nor of producing in us the sensation of light.

When a beam of white light falls upon an opaque body it is decomposed. Some of its primary colours disappear, while others are reflected. It is these reflected rays that render a body visible; produce its colour, and peculiar appearance. When none of them are reflected, the colour is black; when one coloured light only is reflected, as is the case with the different colours of the spectrum, when they are thrown upon white paper, the part or body is seen of that colour only. In a dark night, when no light falls within the horizon, no colour can be reflected, and every body then is black and invisible.

When caloric is accumulated in bodies, when they are heated to a certain extent, they become luminous; they are then visible from their own emitted light; which may be of different colours. There are various bodies also that have the property of emitting light in small proportion, independently of, and without heat. These bodies are named phosphorescent.

1. The brilliant scintillation of the glow-worm in the dark is familiar to us. The same property appears in numerous marine insects, which are occasionally seen collected in vast numbers on the surface of the ocean; giving it the appearance of liquid fire. In these insects, the property appears to be lost upon their loss of vitality.

2. The flesh of many kinds of fish, obtain this property

shortly after death; and as putrefaction comes on, it disappears.

3. Many minerals exhibit this property upon being heated, in different degrees below ignition. Fluor, or Derbyshire spar, native phosphates of lime, and many other minerals, have this property.

4. A similar light is produced by the friction of a great variety of bodies, such as flints, grit-stones, and numerous minerals, sugar, hair, furs, &c. In these cases, this light should be distinguished from the electric light, which the same bodies may be said to produce.

5. Many chemical compounds, such as Canton's, Baldwin's, and Homberg's phosphorus, &c. possess this property in a considerable degree. It seems, in them, to wear out by use, and to be capable of renewal by exposure to ignition, or to the sun's rays.

6. Rotten wood is phosphorescent while moist.

The influence of light over the properties of animal and vegetable bodies, during their developement and growth, is gradual, but extensive, and remarkable. Deprived of light, their functions become languid and imperfect: they grow up weak, flaccid, and stunted. Vegetables never obtain their natural flavour and appearance, but become flaccid and etiolated. Leaves owe their green colour to the solar beams, the petals of flowers, and the wings of insects, their varied and brilliant hues.

Article 5. Of Caloric.

Section 1. *General Remarks.*

By caloric, or heat, is meant the agent, or cause of the sensation of the warmth, which is produced in us by the application of a heated body to the skin. By its accumu-

lation in a body, it raises its temperature, renders it luminous, and ultimately alters its state of aggregation.

It has been already stated that nothing is known of the nature of caloric, beyond the changes we perceive it to produce, in its action upon matter.

The opinion has of late gained ground, that the phenomena of heat are dependent upon certain motions among the elementary atoms, or points of matter, produced by the excitement of energetic chemical actions. That caloric is evolved during chemical action, in many cases, and that its intensity increases proportionably to the intensity of chemical action, is undoubted; but it is difficult to conceive that phenomena, so extensive, permanent, and regular, can depend merely upon a secondary affection, a motion, a revolving of material atoms upon their own, or their mutual axes.

Caloric, in many of its properties, has a strong analogy to matter. It enters into chemical combination. It is evolved again by decomposition. Its quantity may be measured by appropriate standards.

At the same time it cannot be collected, and insulated in a vessel; and subjected to our senses, as matter can. Its parts are repulsive of each other, we perceive no attraction between them. Some of the material chemical elements, however, while under the influence of the voltaic battery, are scarcely removed from the same difficulty.

Caloric, while in an uncombined state, cannot be confined. It pervades all matter, and in its transfer from place to place, eludes our senses, frequently appearing in prodigious quantities, we cannot tell how. But when water is decomposed in the voltaic circle, do we understand how, or, speaking precisely, where it is decomposed? or, in what manner the two elements, oxygen and hydrogen, arrive at their respective poles, where they first appear? Do they not, for a time, equally elude our senses?

Let it be considered, further, that we are by no means acquainted with all the properties of those elements, which all agree in calling material. They have certainly properties beyond the reach of our senses, or of our reasonings.

Caloric, like electricity, appears to be universally diffused through matter; nor can they, by any art, be totally separated from it. We do not know what may be the properties of a body that is wholly deprived of caloric. The most intensely cold body that has been examined, was not freed from it. Heat, in relation to matter, may be considered as a chain, the lower end of which has not yet been come at. By temperature, must be understood a part of this chain, which, for convenience, is measured from a point that is arbitrarily fixed, without consideration of its distance from either extreme.

The affections of caloric with matter, may be divided into those which may be considered as the actions of free caloric upon matter; and those connected with chemical combinations.

Free caloric has a tendency to spread itself through all bodies, by contact, or communication, from particle to particle, producing a communication, or equalization of temperature. Free caloric is diffusible by radiation also. It is, in consequence, unconfineable in any body, or within the cavity of any vessel.

It is produced frequently in large quantities where there is no chemical combination going on, and where we have no conception whence it is derived. This is the case when it is excited by friction; but it gradually escapes again, by the way just pointed out.

In chemical combination, caloric is frequently set free, or excited in large quantity; at other times it disappears and seems to enter into combination with the material chemical elements: and there to exist, dormant, until again rendered free by chemical decomposition. Chemists, in

consequence, have been accustomed to consider it as a variety of matter; speaking as decidedly of the matter of heat, as of the matter of water. But this mode of expression is apt to mislead, by confounding, under one name, things that should be distinguished. Caloric appears to be evolved frequently; not simply in proportion to the quantity of matter decomposed; but rather to the intensity and force of the chemical action, and the time of its continuance.

Man, like the bodies around him, is in the midst of caloric. He could not exist without it; and his existence in it is limited to a very short range of temperature. The earth is so situated, that the temperature of it is wonderfully adapted to this limited capacity. It derives the greater part of its heat from the rays of the sun. From its globular form, and the inclination of its poles, the different regions are necessarily unequally heated; and the temperature of each region is subject to numerous variations. But the extremes of these variations are limited, and susceptible of further limitation by artificial contrivances. A very large portion of its surface may, consequently, be inhabited by man.

Section 2. *Sources of Caloric.*

The sources of caloric, whence it may be produced or accumulated, are,

1. The solar rays.
2. Electrical excitement.
3. Friction and percussion.
4. Chemical combination and combustion.

The solar rays are the great source whence the caloric of the earth is chiefly supplied. They supply it with a large quantity, but from the form of the earth, the supply is

distributed very unequally to different parts of it; and although the obliquity of the ecliptic tends to equalise it to a certain extent; still the poles are left in eternal frost, while the heat is accumulated between the tropics.

The rays of the sun may be brought to a focus by a convex lens of glass, of water, or of any dense transparent body; and thus a degree of heat may be obtained that is superior to the heat of the strongest blast furnace. Gold, which will resist, for months together, the heat of the strongest glasshouse furnace, may be evaporated by the solar heat brought to a focus by a lens that is three feet in diameter.

Of the heat excited by electricity we have already spoken.

Friction between solid bodies, appears to be capable of exciting heat in an almost unlimited quantity. Some Indians obtain fire whenever they want it, by friction between two pieces of wood. In the action of wheel-work, when the friction is not avoided, so much heat is sometimes produced as to set fire to the machinery. A mixture of grease and plumbago, with a very little tar, is the best application known for lessening friction.

This caloric has been supposed to be pressed out of the iron where it previously existed, by the mechanical force applied to it. But in the friction between a cast-iron cannon and its blunt borer, the quantity of caloric excited, so far exceeds all proportion relative to the quantity of iron that is abraded, as entirely to invalidate this opinion.

Mechanical force, any how applied, excites caloric. Every one knows that the percussion of flint upon steel produces sparks, hot enough not merely to fire tinder, but to fuse the particle of steel that is struck off. An iron rod, by a succession of blows with a hammer, while resting upon an anvil, may soon be made red hot. A small portion of a gas when confined in a tube, and suddenly condensed

into about one-fifth of its volume, will evolve heat enough to fire gunpowder, tinder, sulphur, or hydrogen gas.

Heat is excited by tension also, or stretching a body. A piece of elastic gum when drawn out forcibly, becomes warmer as it is extended. When a bar of iron is stretched by a force that overcomes its cohesion, it becomes very hot at the extended part before it lacerates.

In every case, perhaps, of chemical mixture, or combination, caloric disappears, or is evolved. Chemical action is, therefore, a most abundant source of heat.

At the temperature of ignition, chemical combinations take place between certain bodies in which light and heat are evolved; sometimes in enormous quantities, producing the phenomena of combustion.

Thus oxygen and chlorine, in combination with hydrogen, and with a great number of bodies, produce combustion. Sulphur, when combining at a certain temperature with iron, or copper, and several other metals; produces the same effect. Combustion is also produced during the formation of several metallic compounds, in which the agency of neither oxygen, hydrogen, nor chlorine, is suspected.

To excite combustion, two bodies are requisite, which have a strong chemical action on each other. During their combination, heat and light are evolved.

Under the technical names, combustible or inflammable bodies, may be included all the electro-negative, and electro-positive chemical elements: and, apparently, all their compounds which are not already combined to saturation with one or other of the electro-negative bodies. These bodies are said to differ in their combustible power; they differ rather in the circumstances of the attractions that produce it. Oxygen and chlorine combine with a slight force, and with no appearance of combustion. On the application of a certain temperature, they again separate with

the evolution of so much light and caloric, as to produce a violent explosion. Chlorine and nitrogen combine as quietly. The combustion, explosion, and expansion, produced by their decomposition, is still more sudden and violent.

Combustion offers the most economical and convenient mode of obtaining an unlimited supply of caloric; and is, in consequence, the most general means of supplying heat for chemical and manufacturing, as well as domestic purposes.

It happens, that a part of the air we live in, and which, consequently, is always present, is most generally one of the combining bodies. This circumstance contributed to confine, for a long time, the chemist's view of combustion. All bodies that were observed to become inflamed, and to burn in the atmosphere, were supposed to give out the light and heat, and were, in consequence, called combustibles, or inflammables.

For ages, combustion was considered as an inexplicable phenomenon. The first plausible theory was that of Dr. Stahl. According to him, all inflammable bodies were supposed to contain an *inflammable principle*, which might be separated by an elevation of temperature, but could not be confined and rendered an object of sense. During its escape, it produced the phenomena of light and heat. Inflammables were phlogisticated bodies; and bodies that had undergone the process of combustion; that is, were deprived of their phlogiston, were called dephlogisticated bodies. A metal was supposed, for instance, to consist of its pure elementary calx, and phlogiston. It was soon discovered, that a metal, during combustion, gained in weight, and that several metals could be readily restored to their metallic state, without the addition of any body that could supply them with the supposed phlogiston. It was discovered also, that these metals, during their reduction, gave out oxygen gas, and that the gas thus given out, was

equal in weight to the increase the metal had received during its combustion.

A modification of the theory of Stahl was introduced to suit this discovery. But the theory was gradually undermined;—the existence of the supposed phlogiston became doubtful, and at last disbelieved. A new theory, the production of M. Lavoisier and his friends, was then generally received. It was considered, not as a theory merely, but as a happy, clear, and necessary induction from facts. Its laws were considered to be as certain and as well proved as the laws of gravitation. It was hailed as the true foundation of chemical science; as such, a new nomenclature was founded upon it, and has been generally adopted.

According to this theory, phlogiston is an imaginary element; oxygen is the universal principle of combustion, and of acidity. A new name was given to it: it was, strictly speaking, the only inflammable. The bodies heretofore called inflammable, acted a secondary part merely. Oxygen gas consisted of the universal acidifying base, united with light and heat. When it entered into chemical combination, and was condensed into a new compound, the light and heat were separated, and became apparent. As the science of chemistry has advanced many anomalies to this theory have been successively observed; heat and light are often evolved in quantities that are very disproportionate to the quantity of oxygen acted upon; frequently very disproportionate to each other. They are sometimes evolved where no condensation takes place; and sometimes where solids are changed into gasses. It was observed, also, that incandescence is often produced, where the presence of oxygen cannot be traced. Acids are met with also that contain no oxygen.

These various anomalies produced various modifications, bolsterings, and exceptions for the support of the theory. The subsequent discovery of the voltaic battery, has ex-

tended the bounds of chemical research, and has, in consequence. led to various other discoveries. These, with the additional discovery that chlorine contains no oxygen, and is apparently a simple element, in its properties very analogous to oxygen; particularly in producing light and heat in many of its combinations, have not only shaken Lavoisier's theory, and every other from their foundations; but have spread an imperishable lustre over the chemist who has been the most active agent in them.

It is now well known that combustion is by no means, any more than acidification, confined to combinations with oxygen. It is produced very generally in combinations with chlorine, with iodine, with hydrogen, and in many other instances.

This more comprehensive view of combustion has again raised the question, whence comes the heat and light. How are they produced? Are they pre-existant in either of the combining bodies, bound up and concealed in chemical combination, until set at liberty from the attraction of their base? Or are they excited and attracted to the part from surrounding bodies, as electricity appears to be; by the forcible chemical or mechanical actions that are produced between the minute atoms? Or do they consist merely in a certain corpuscular motion among the atoms of the heated body excited by the energetic force of the chemical actions that are going on, and consequently gradually ceasing as the chemical action abates? An opinion something like the latter, appears to be entertained by some of the ablest chemical philosophers of the present day. But it is an opinion only.

When a combustible body, such as coal, wood, peat, charcoal, sulphur or phosphorus, is heated to a certain temperature in atmospheric air, a chemical combination begins between the body and the oxygen gas, that is contained in the air. Light and heat are given out, as long as

the chemical action is going on; and, consequently, by keeping up the temperature, they promote their own evolution.

When chlorine gas is let into an exhausted receiver, containing a portion of a metal, of copper foil for instance, or powdered antimony, they instantly combine with evolution of light and heat, and they are condensed into a solid. Hydrogen and oxygen combine to form water, and during their combination light and heat are evolved.

In these, and in numerous other cases, it may, with plausibility, be maintained, that the light and heat are evolved from the gasses, in consequence of the superior attraction of the bases of the gasses for other bodies, with which they form condensed compounds; setting at liberty the heat, and light which supported them in their elastic state. But, combustion, of the most energetic kind, is produced in many cases where there is no condensation; and in some cases where there is a great expansion. Chlorine and oxygen may be combined. They produce a gas which when gently heated explodes, and expands one-fifth in bulk. A number of explosive powders expand in a much greater degree. Chlorine and nitrogen combine into an oily like fluid. According to all chemical theories it should be totally divested of any inflammability. It is the most violently inflammable body that is known. Upon the slightest friction it explodes with unequalled rapidity and force; expanding into a gas which occupies more than 600 times its former bulk. A lump, the size of a pea, is dangerous to handle. Here, according to theory, not heat, but intense cold, should have been produced. Gunpowder also, is decomposed with prodigious expansion of its elements, and with an evolution of light and heat. But, according to all the theories that have been hitherto invented, a most excessive cold should be produced.

Those bodies which by their combination produce the

phenomena of combustion, have been distinguished into combustibles, and supporters of combustion. These names, arising from an imperfect theory, are apt to mislead. Since, when two bodies combine producing combustion, it is unknown how the phenomena are produced; it cannot be known which is truly the combustible, or which the supporter of combustion, supposing the terms not improperly applied. Thus much however appears, the body, which in one case is supposed to be a supporter, must in another case be supposed a combustible. A compound of hydrogen gas with sulphur for instance, when it combines with oxygen, or with chlorine, is considered as a combustible. When it combines with potassium it is considered as a supporter of combustion. According to the same notion, sulphur, which is a combustible in its combinations with oxygen, is a supporter in its combinations with most of the metals.

Combustion commences between different bodies at various temperatures. Some take fire immediately on coming together at a low temperature. Phosphuretted-hydrogen inflames on coming into the atmosphere. Many metals inflame in chlorine at the same low temperature. Phosphorus inflames in atmospheric air at 148° Farenheit. Sulphur at about 550°. Iron wire burns in oxygen, when heated a bright red heat, and it burns with great brilliancy. Diamond takes fire in the same gas when heated to a white heat, and then evolves a sufficient quantity of heat to support its own combustion. In the heat excited by electricity or by the oxhydrogen blow-pipe, gold and platinum take fire and burn.

Combustible bodies, in a gaseous state, take fire also at different temperatures. Thus biphosphuretted-hydrogen inflames as it comes into atmospheric air at a low temperature. A mixture of oxygen and hydrogen gasses is fired at a low red heat. According to Sir H. Davy's experiments, a

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wire, one-fortieth part of an inch in diameter, at a bright red heat, will inflame hydrogen in the atmosphere. A wire of one-five hundredth part of an inch, heated to whiteness, will do the same. A wire of one-eighth part of an inch, heated to dull red, inflames carbonic oxide: when ignited to a bright red, it inflames olefiant gas: to inflame subcarburetted-hydrogen, it must be ignited to whiteness.

When bodies that produce combustion are previously well mixed, the inflammation is rapid; sometimes an instantaneous explosion takes place, as in the combustion of mixed gasses, or explosive powders. When one or both of them is supplied gradually, as when a jet of hydrogen burns as it flows into the atmosphere; or a jet of oxygen as it flows into a balloon filled with hydrogen; or when coals or any solid hard aggregate combustible is burning, the combustion goes on at the point of contact and continues regularly, as long as the supply is continued.

Bodies are disposed to combustion in different degrees, according to the force of their attractions. Thus, when into a long-necked bottle, filled with atmospheric air, a burning taper is introduced, in a short time the flame disappears. If now another burning taper be introduced, it is extinguished immediately. If a small tube, containing zinc and diluted sulphuric acid, be now introduced, with the hydrogen jet inflamed, the hydrogen will burn for some time. When this flame disappears, if burning sulphur be introduced, it will burn for some time. If then a bit of phosphorus be introduced, and the tube warmed, the combustion of the phosphorus will produce a pale yellow flame.

When combustion is excited in atmospheric air, it will continue, until the body, or the oxygen of the air is saturated; or until, in consequence of the caloric being carried off more rapidly than it is produced, the burning body is cooled below its inflaming temperature; then it ceases.

Gasses, like solids, have, as has been said, the property

of inflaming and burning at different temperatures. It is upon the property of gas liberated in coal-pits—an impure subcarburetted hydrogen—not to inflame except at a high temperature, that the celebrated safety-lamp of Davy is constructed. It consists of a woven wire web, which is so dense as, by its cooling and radiating power, to prevent the passage of the burning flame through its apertures; at the same time that it permits sufficient light to pass for the use of the workman. As the inflamed air within the lamp passes the web, the metallic wire absorbs so much of its heat as to leave no danger of its inflaming the external gas.

Gasses are transparent, and, in consequence, invisible, even when heated to a high temperature. What then is flame? How is light produced by the flame of candles, oil, gas, &c.?

In most of our illuminating gasses, hydrogen is a principal ingredient. It may be considered the best and most general menstruum in the formation of illuminating gasses. Pure hydrogen may be heated, until it communicates a white heat to a metal immersed in it; but is itself invisible. During its combustion with oxygen gas, an enormous quantity of heat is evolved, but very little light. During its combination in atmospheric air, more light is evolved, and the heat is much less. In both these cases, the illuminating power seems to depend upon the slight opacity produced, by the admixture of gasses of different densities, and by their combination. It appears, that where there is no opacity produced, there is no illuminating flame. The best illuminating flames are produced by compound gasses, consisting of a solution of an opaque inflammable body; which, during the combination, is precipitated in opaque reflecting corpuscules; and the more condensed they are, the more the flame illuminates.

In the flame produced by oil, tallow, and wax, as well as by coals, combustible gasses, or vapours, are first produced;

the wick serving as a focus, or fire-place, where the gasses are formed; and whence they pass into the air. When the wick is inflamed, the combustible matter passes into it, in a fluid state, by capillary attraction, and is converted into a gaseous state.

Oils, tallow, wood, coals, or any bodies capable of yielding combustible gasses, may as is well known, be decomposed and distilled in close retorts, and the compound gasses produced from them collected in vessels for future use.

The gasses thus produced, consist chiefly of hydrogen holding carbon in solution, mixed with an uncertain proportion of hydrogen, and of a gas composed of carbon and oxygen. The larger the quantity of carbon present, the brighter the flame, and the stronger the light. Hence it is, that pure olefiant gas, a saturated compound of carbon and hydrogen, produces a most brilliant and dense light. Oil gas is superior to coal gas, because it contains a larger proportion of this olefiant gas.

On examining the burning flame of a large candle placed in still air, the wick being kept rather short, it is observed to assume a conical form, with a rounded base. In the central part, round the upper portion of the wick, is a dark, or rather unilluminated subtransparent cone, consisting of the newly formed gas, partly unmixed as yet with the oxygen of the air. Directly surrounding this is a cone of very bright light. This part is produced by the mixture and combination of the gas with the oxygen of the air. The carbon appears to be precipitated in an opaque state, by the imperfect chemical action that goes on, in the central part; and then to be carried into the hotter part of the flame, where, by its strong reflection, and high temperature, it produces the dense brilliant light.

Surrounding these is a cone of more diluted light. At the base, its colour is blue; it becomes very thin as it

rises up the sides, and thicker as it envelopes the summit of the bright cone. The heat of this blue flame is intense, and the combustion of the gas, which supplies this part of the flame, is complete. Little light is, in consequence, produced by it. Gradually diluted with atmospheric air, it vanishes as the combustion is completed. The hottest part of the flame appears to be at the exterior surface of the bright cone, where the combustion is most complete, and the precipitated carbon is combined.

When a fine wire of platinum is held horizontally across the flame of a candle, the hottest part of the flame is demonstrated by the brilliancy of its ignition, and the consequent apparent increase of its diameter.

What is called a chemical blow-pipe is a large candle, or lamp, into the central part of the flame of which a current of atmospheric air, or of oxygen gas, is forced through a tube, with a minute aperture. The flame is thrown into an horizontal position, and a long narrow blue cone is produced in its centre. At the extremity of this the heat is the most intense, and the combustion the strongest.

Too intense a heat diminishes the light of flame, by burning the gas in an undecomposed transparent state. Such an elevated temperature is necessary, on the other hand, as can produce a bright ignition of the evolved opaque matter, and then completely burn it off, and prevent smoke.

The gas being spread out into a thin sheet, to both sides of which a currents of atmospheric air has an uniform, but limited access, as in the lamps first described by Dr. Lewis, and now called Argand lamps, the glass promoting the perpendicular current, and protecting the flame from being disturbed by cross-currents, or the too sudden abstraction of caloric; produces the brightest and clearest light, and the most complete combustion.

The extreme brilliancy of burning iron, zinc, and more

particularly of phosphorus, is produced, in a great measure, from the ignition of their solid opaque products.

It has been proposed to introduce into flame, in some cases, a web of platinum, or some other porous indestructible body, that, by the brightness of its ignition, it may increase the light.

The intensity of light from burning gasses is increased by condensing them; and diminished, on the contrary, by rarefying them.

It appears from the experiments of Sir H. Davy, on the safety-lamp, that combustion may be carried on, with a certain rapidity, without the evolution of light. A mixture of oxygen and hydrogen gasses, in a due proportion to form water, is converted into steam, without explosion or inflammation, by passing it through a tube, heated a little below ignition.

Chlorine unites with hydrogen, at a lower temperature than oxygen does.

Charcoal unites with oxygen rather rapidly, evolving no light, and apparently but little heat, at a temperature not much above the boiling point of mercury.

At a dull red heat, olefiant gas is decomposed, and its elements combine with oxygen, without light or explosion. If, during these experiments, the heat become too much elevated, inflammation and explosion ensue.

When a fine platinum wire, heated almost to ignition, is immersed in a mixture of an inflammable gas and atmospheric air, it becomes ignited to a bright glowing red, and continues so for a length of time. When the ignition has ceased, the gas is no longer combustible.

The same phenomenon is produced, when ether, alkohol, oil of turpentine, or camphor, are employed. When, to a common spirit lamp, a spiral coil, consisting of about sixteen convolutions of fine platinum wire, about one-hundredth part of an inch in diameter, is so applied, that about one-

half of the convolutions may project above the wick, if the wick be inflamed and blown out, the projecting convolutions will continue red hot. The spirit will continue rising in a gasiform state, and will undergo an invisible combustion, keeping the wire red hot until all the spirit is exhausted. A cylinder of camphor, heated in a similar way, produces the same phenomenon.

The combustion of wood, coal, charcoal, and turf, furnish the most regular and convenient supply of caloric for domestic use, or for the chemist, or manufacturer; and for this purpose, a great variety of fire-places, furnaces, stoves, and grates are contrived, and more or less varied, to adapt them to particular uses or fancies.

Every stove, or fire-place, may be considered as requiring six parts, two or more of which are sometimes united.

1. The focus, or space, to hold the burning fuel.

2. The ash-pit, or space to receive the incombustible remains.

3. An aperture for the due supply of air.

4. An opening for the occasional supply of fuel.

5. A place for the bodies that are to be subjected to the action of caloric; and

6. A chimney to carry off the smoke and incombustible part of the air.

Wind, blast, and reverberatory furnaces are in great variety, and produce an intense, or a regulated heat. They are constructed of the most indestructible materials, and should be surrounded with the most imperfect conductors of caloric.

The fire-place is separated from the ash-pit by an iron grate, through which the ashes fall, and the air has a free passage.

That the supply of air may be proportionate to the extent of combustion, the ash-pit should be supplied with a door, or damper as it is called. It should fit close, and

have a hole in the middle of it, furnished with a sliding plate, which is capable of wholly or partially closing it. The area of this hole should not exceed the area of the openings in the grate, and this rarely requires to be fully opened.

The fuel is generally supplied through the same aperture through which is introduced the body to be exposed to the action of heat.

The body may be exposed either to the naked fire, or inclosed in a proper vessel, according to its properties, and the whole surmounted with the chimney. If the passage into the chimney be lateral, it should be placed so high up as not to draw off the heated air before it has performed its office. The opening into the chimney should be wider than the opening of the damper. A wider chimney is requisite for a coal than for a wood fire, to leave room for the large quantity of soot that is usually produced. But good wind and blast furnaces produce comparatively little soot.

Domestic coppers and boilers are usually very ill set; the waste of fuel is in consequence very great, and the fires unmanageable. The aperture of the ash-pit should be closed by a door that should be placed at the front of the brick-work, and be furnished with a sliding register.

The door to supply the fuel by should be fitted closely to its frame, and should also be placed in the front of the brick-work, directly over the register door.

The fire-place should be thrown back under the centre of the boiler.

The grate, or bars of the fire-place, are in general too extensive; and the fire-place is consequently too large. For a thirty-gallon boiler it need not exceed an area of eight inches square: but the focus, or fire-place, about four inches from the bottom should expand freely, and open all round the boiler, to allow a free passage for both

the heated air and the radiating caloric. For the same reason the fuel should be supplied in small portions, and the surface of the fire kept as clear as possible.

When more flues than one are carried into a chimney, a separate damper becomes necessary to each flue; but where a fire-place has its proper chimney, the ash-pit register is damper enough.

The atmospheric air, without which the combustion cannot go on, is a mixed gas containing four parts of nitrogen and one of oxygen. During the combustion a chemical action is going between the oxygen and the fuel; the nitrogen passes through the fire unchanged in its chemical properties. Its temperature, however, is much raised, and it is proportionally expanded. Its specific gravity being thus diminished, it is forced up the chimney rapidly by the pressure of the colder and heavier external air passing in through the ash-pit; and it generally carries away with it a quantity of unconsumed charcoal and other bodies, thus constituting the smoke, and giving rise to what is called the draught of the chimney.

When more air is permitted to pass through the fire than is necessary to supply a due proportion of oxygen, the draught of the chimney no doubt is increased, so is the roaring of it, but a quantity of caloric is, without necessity, carried away. When much caloric is wasted in this way, the fuel becomes so much cooled as to be imperfectly consumed, and thus a further loss of heat is produced.

To render the draught of a chimney free and manageable, it is necessary that all parts of the fire-place be air-tight. A certain height of the chimney is necessary to produce a due current; but the force of the current is best regulated by an ash-pit register.

When the door is properly placed, it is removed forward from the fire by the thickness of the masonry. This space may be kept partially filled with fuel. It will not burn to

any depth without air; it helps to stop the passage of the air through any crevices that may be round the door; it also intercepts the escape of caloric, and being partially warmed, it cools the fire less when thrown upon it.

The open domestic grate, or fire-place, to which custom has so strongly attached the English, has many incurable defects; and these are often increased by their bad construction. The width of the opening above the grate is mostly unnecessarily large; and too great a mass of iron-work generally surrounds the fire. The inconveniences from both these sources might be very much ameliorated, if custom, prejudice, fancy, or taste as it is called, and the grate venders did not prevent it.

The air which supports the combustion has too free access in an open fire-place, to both the front and bottom grating. The oxygen is in consequence only partially consumed. A larger supply of air is required, a great deal of heat is carried off by it, and the combustion rendered imperfect by being carried on at a lower temperature.

The mass of iron that usually holds the fire, at the same time carries away a great quantity of heat. The co-operation of these effects render the fire dull, and the fuel, unless it is very inflammable at a low temperature, is imperfectly burnt; and consequently wasted, while comparatively little heat is derived either by radiation or communication.

At the same time, the open chimney entrance conducts, like a funnel, all the warmed light air that is round the fire-place, up the chimney; cold air supplies its place, and as soon as it is warmed follows it. Thus is produced a rapid current of cold air into the room from the doors, windows, and every chink around; and a rapid current of warm air out of it up the chimney. The colder the external air is, or the larger the fire is, the stronger the current. The consequence is, that in severely cold weather, an English dwelling-room cannot be, without great difficulty, and

generally speaking is not, kept sufficiently warm. While one side of the body is exposed to a roasting radiant heat, the opposite side is chilled by a rapid current of cold air. And yet we are astonished at the general prevalence among us of pulmonary complaints, and of the extensive destruction of human life they occasion.

These inconveniences may be lessened, in a degree, by more attention to the construction of fire-places, on the part of persons who are to use them; and who are, consequently, most interested in their own health and comfort.

The focus, or fire-place, which should be proportioned to the size of the room, should be placed as low as the space necessary for the ash-pit will permit. When the floor is well warmed with radiant heat, the ascent of the heated air will warm the central parts of the room. The bearing and front bars must be made of iron, but the other three sides of the fire-place should be constructed of fire-bricks, or of any incombustible that is a bad conductor of caloric; or, if iron be used, it should be set solid with them. The sides should be perpendicular, and if they are placed at an obtuse angle with the back, the front is spread out, and has more space for radiation: the heated sides of the stove radiate also.

The chimney-piece should be as low, and as short in width, as convenience will permit; and the inner side contracted into a funnel, to form the entrance of the chimney. The dome, or funnel may be constructed partly of iron, with a door above, to let the sweeper pass, or to regulate the occasional size of the opening. This opening should be nearly perpendicular above the burning fuel, but, at the same time, rather backwards. It should at all times be no wider open than is necessary to carry up the smoke, and the space required for this is less than is generally supposed. Its form should approach to a square, or a circle, and not to an oblong slit. The area need not exceed two-

thirds the area of the bottom grating, and is seldom required so wide.

"But although the opening of the chimney should be contracted, to prevent, as much as possible, the current of warm air from the room; the chimney itself must be wide enough to leave room for the probable accumulation of soot, and for the sweeper to remove it.

In old houses, the throats of the chimneys are, in general, unreasonably large: the rooms are very liable in consequence, to be filled at times with smoke; to be rendered very uncomfortable from the rapid current of air up the chimney, when there is a fire; and frequently when there is not, from a current downwards. The inconvenience may in most cases be relieved by a simple contrivance.

When the iron-work that forms the back and sides of the focus can not be removed, let it be set solid with brick-work. Contract the open space above the fire-place as much as is convenient, and carry the masonry perpendicularly upwards, to about eight inches above the inner side of the sill. Then lay on a flat iron plate, that has a hole in it, perpendicularly over the fire-place. The hole may be five, six, or seven inches square, according to the size of the fire-place, and may have a door to close it occasionally.

Provided iron be excluded from the back and sides of the burning fuel, it may be employed in other parts, in any quantity; either for strength or ornament. Polished iron or steel reflects very powerfully the radiant heat that falls upon it.

The quantity of caloric evolved during combustion, is of course very various in different bodies. It varies in the same bodies also, according to the rapidity with which the combustion is carried on.

It appears, generally speaking, that, in combustion with oxygen, all circumstances being as nearly equal as possible, the quantity of caloric evolved is in proportion to the quan-

tity of caloric evolved is in proportion to the quantity of oxygen consumed; and consequently, that those bodies which combine with the largest quantity of oxygen may be called the most highly combustible.

So many precautions are required in experiments upon this subject, that remote and unsatisfactory approximations only have been obtained, and sometimes contradictory. The experiments of different chemists agree, however, in shewing that hydrogen, during its combination with a given quantity of oxygen, evolves a larger quantity of caloric than any other body. This might have been expected, whether we consider the force and temperature of their combustion, or the enormous condensation which follows, when it is in a gaseous state, nearly 2000 volumes being condensed into one volume.

In practice, the next body to hydrogen in its power of evolving caloric, is carbon; and those substances that are composed of carbon, and condensed hydrogen; as bitumen and coals; after these, dried wood and turf. Their proportionate effect is increased, by burning them in large masses, and at a high temperature, by their being surrounded with non-conductors, and by the caloric passing to the body acted upon through a good conductor.

In a well built stove, it appears from the experiments of Dr. Black, Mr. Watt, and others, that one pound of very good coals, or three pounds of wood, will convert from seven to eight pounds of water into steam; and that in order to produce steam at the rate of one cubit foot per hour, the boiler must have eight feet of surface exposed to the fire.

Section 3. *Radiation of Caloric.*

By whatever source caloric is excited, or accumulated,

it has a tendency to spread, and diffuse itself again; and thus to bring all bodies to the same temperature.

It is convenient to consider the affections of heat upon matter in two points of view, although it is difficult to distinguish strictly the boundaries of each.

Firstly, Caloric affects matter mechanically, as it may be called, extending itself through it in every direction, either by contiguity, or radiation; elevating its temperature; extending it, and changing its state, from a solid to a liquid, or gas.

Secondly, It is extensively connected with chemical actions; it affects the order of chemical attraction among bodies very powerfully, rendering them variable according to their variation of temperature. It is absorbed, or evolved, in almost every case of chemical decomposition, or combination. So general is this change, that variation of temperature is considered, in obscure cases, as a proof of chemical action. Frequently, as we have already shewn, the quantity of heat evolved, is very great; frequently a great quantity appears to be absorbed, and to enter, as an ingredient, in chemical combinations.

Free, or, as it is sometimes called, uncombined caloric, spreads itself abroad through bodies in two ways; by radiation, analogous to the radiation of light, and by contiguous communication from one particle, or atom of matter to another.

It has been known for ages, that the sun radiates heat as well as light, and that the heat of the sun is refrangible, and susceptible of being reflected, as light is. Archimedes is said upon one occasion to have burnt a Roman fleet, by reflecting the heat of the sun from a number of reflectors, reflecting all that fell upon their surface to one point or focus. But that heat is susceptible of radiation distinct from light, and apparently independent of it, was not observed until the late Dr. Herschel called the attention of

philosophers to it. Every day's observation, however, shews, that this property, which has so long been confounded with the diffusion of caloric, by contiguity, operates very generally and extensively.

Free caloric, as has been observed, is present in one proportion or other in all bodies. Whenever a body is in a transparent medium, it radiates caloric, more or less, according to its temperature, and according to the nature of its surface.

The heat thus radiated is refracted, as light is, in passing from one medium to another; and is reflected from polished surfaces at an angle that is equal to the angle of its incidence.

Radiation is most free through a vacuum, at least through such a vacuum as the chemist can subject to experiment. It appears to be equally free through all gasses that are equally transparent, nor do the winds nor motions of the air appear to affect it. As the air becomes foggy or opaque, radiation is interrupted, and opaque bodies intercept it. Glass, water, and dense transparent bodies, transmit the heating rays of the sun, as well as the light of it, with freedom.

The heat radiating through the air from bodies artificially heated is not transmitted with equal freedom. The heat radiating from a furnace, or from a ball of highly ignited iron, will raise the temperature of a thermometer placed at a distance. If a pane of glass be interposed it will still affect the thermometer, but to a less extent; a part of the rays will be intercepted. As the body becomes cooler a larger proportion of its rays is intercepted by the glass, and at length the whole are intercepted. The heat interrupted by the glass is divided; a part of it is reflected to surrounding bodies, but the greater part is retained, and raises its temperature, and consequently increases its own proper radiation. The thinner the glass is the less apparent are these phenomena.

The radiation of caloric is altogether intercepted by opaque bodies, until they become heated, and then caloric radiates from them. Thus a clear pane of glass intercepts but little of the heat from a sun-beam, while it intercepts a great part of the heat from the opening of a glass-house furnace. But a thin sheet of tin-foil or gilt paper intercepts the whole.

Heated opaque bodies radiate caloric more or less freely, according to the texture, the polish, or the colour of their surfaces.

When a tin vessel filled with boiling water is placed in the focus of a metallic concave reflector, opposite to which, at the distance of a few feet, is placed a corresponding reflector, with a delicate thermometer in its focus: the thermometer will be affected differently, according as the opposed surface of the tin vessel is covered by bodies of different radiating powers.

Thus, according to the experiments of Mr. Leslie, in which he estimates the radiation of water, supposing it were not interrupted by the vessel, at 100.

When the tin vessel is covered with lamp-black its radiation is equal to - - - - - - - - - - - - - 100

Covered with	Writing-paper	98
	Rosin	96
	Sealing-wax	95
	Crown-glass	90
	China-ink	88
	Red-lead	80
	Plumbago	75
	Isinglass	75
	Tarnished-lead	45
	Clean-lead	19
	Polished-iron	15
Polished tin-plate, gold, silver and copper		12

Upon scratching the surfaces of the polished metals the radiation from them is much increased.

If the air be in motion during these experiments, the difference in the result is less remarkable, in consequence of the conducting power interfering with the radiating.

Bodies that radiate heat most abundantly are found to absorb most abundantly, the heat that falls upon them. When surrounded with hotter bodies they become heated more rapidly; and when surrounded with colder, they cool more rapidly, than those which radiate less. The heat that falls upon bodies is not lost, as a great part of the light in most cases appears to be; the whole of it is reflected or absorbed, producing temperature, which is spread in the usual manner, by contiguity or radiation.

There are no surfaces that do not reflect a part of the caloric that falls upon them; nor are there any that do not absorb a portion of it.

Those surfaces which radiate most freely, absorb caloric most freely, and are the worst reflectors; while such surfaces as are the best reflectors are the worst radiators, or absorbers of caloric. Polished surfaces consequently are the best reflectors; and although generally the best conductors, yet are they the worst radiators, and the longest in cooling when heated; and, as being the worst absorbers, the longest in becoming heated, by radiation, when cooled.

China, glass, porous earthenware, are comparatively imperfect conductors of caloric, and yet they cool more rapidly than metals.

A discrimination of these properties of bodies may frequently be made with advantage, in various arts and uses, as well as by ladies in the selection of their tea-pots, which has been so often, and so gravely recommended, by almost every chemical writer.

Hot bodies, as has been said, radiate freely in all directions. Place a heated body in the focus of one of Pictet's

metallic reflectors, a thermometer placed in the focus of the other rises instantly, and continues rising, in proportion to the heat that is radiated. Remove the heated body from the focus, and place a ball of ice in it, the thermometer instantly falls to a temperature which is proportional to the coldness of the ice. This phenomenon has induced a notion that cold may be a positive element It is the natural consequence of the law of *general* radiation; and is one of the best proofs of it.

All surrounding bodies from whence straight lines can pass to the surface of the mirrors; radiate heat upon them, according to their temperatures, their radiating powers, and the respective quantities of *direct* surface. When the quantities, radiated upon the two surfaces are equal, no apparent effect is produced, the quantity of caloric reflected from the surface of one mirror counter-balancing that reflected from the other.

But when a ball of ice is placed in one focus, it absorbs the whole of the caloric that radiates upon it, or upon the surface of the mirror; and it radiates none in return. The thermometer, therefore, that is in the opposite focus, as well as all the bodies that were radiated upon, being suddenly deprived of so much radiant caloric, while they continue radiating; are rapidly reduced in temperature.

The colour of bodies, all other circumstances being the same, affects their absorbing or radiating power

Bodies have, strictly speaking, no colour, but some peculiar arrangement, or texture of the atoms which forms their surfaces, and gives the property of decompounding the white light falling upon them, and of reflecting certain colours only. That the same property of surface should variously affect the radiation of heat also, might be expected. Thus, when a mercurial thermometer is covered with metallic foil, and exposed to the sun's rays, it is heated, and the mercury rises several degrees; cover it

with white paint, and it will rise higher; paint it red, and it will rise still higher; paint it black, and a still greater proportion of caloric is absorbed.

This was illustrated by Dr. Franklin with four bits of cloth of different colours. He placed them on the snow in the sunshine. On examination, after a short period, a piece of black cloth had sunk in the snow to a considerable depth; a piece of blue had sunk, but not so far; a piece of pale brown had sunk still less; and a piece of white had scarcely sunk at all.

The formation of dews and hoar frosts affords a beautiful instance of the effect of radiating caloric, as explained by Dr. Wells. Dews are the most abundant in cold, calm, clear nights, succeeding to warm days; at which times, the air contains a large proportion of hygrometric water. On cloudy windy nights, no dew forms until the wind dies away; nor then, unless the clouds are high and the air clear. If dew has formed, it gradually disappears, on heavy clouds obscuring the horizon, or on winds rising.

They may begin to fall soon after sunset, continue through the night, and for a time after sunrise. Or their formation may be interrupted during the whole, or any part of this time. After sunset the earth's surface continues, as before, to radiate caloric into the expanse of the heavens. On cloudless nights, when the air is transparent, it receives no return. The temperature of its surface, and of the radiating bodies that are on it, consequently cools. When the expanse is veiled with clouds, they, unless they are very distant, return radiant caloric in nearly an equal proportion, and then, there is but little, or no formation of dew. Otherwise the radiation gradually abstracts heat from the surface of the earth, and the bodies that are upon it.

Hence it is, that delicate vegetables are often preserved from the frost that they would be exposed to on a clear

cool night, by spreading a matting, or an opaque awning between them and the expanse above, to return them a portion of radiant heat.

Where the surface is coated with a good conductor of caloric, as gravel mould or metal, the lost heat is supplied from the earth by contiguous communication, and then no dew appears. But vegetable bodies in general are bad conductors of caloric, more particularly grasses and herbaceous plants, while their leaves are very extensive radiating surfaces. The temperature of grass, or of shrubs and foliage is frequently lowered in this manner, 10° to 15° 20°, or even to 30° below the temperature of the subjacent earth, or of the air a few feet above them. They consequently cool by contiguous communication, the adjoining air, and precipitate its moisture in the form of dews; the dew being more abundantly produced, as the air was previously warmer, and more charged with hygrometric vapour.

Metallic disks, when laid lightly upon the grass, so as to have no communication with the earth, but through the grass, will lose temperature by radiation, and then become dewed, while the adjoining gravel earth or disks of metal laid upon them will not.

In Bengal, ice is produced in considerable quantity in favourable nights, by the effects of radiation. A number of shallow porous pans are arranged upon a thick layer of straw or reeds, and surrounded with a low bank of earth to prevent the circulation of air, with the surface exposed to the clear heavens. As the caloric radiates from the surface of the water, cakes of ice form and are successively removed.

Dr. Wollaston's etherioscope shews the proportionate radiation from the heavens with great delicacy. It is curious to see the thermometer of it affected by every passing cloud.

The earth is warmed by the heat that radiates from the sun. The parts that are most exposed to its rays are consequently the hottest. Between the tropics, the heat falls direct and dense; towards the poles, its incidence is more oblique and scattered.

The obliquity of the ecliptic, in some degree, relieves the equator from the accumulation of caloric which would otherwise be thrown on it, and spreads it rather more over the polar regions. A large quantity of caloric is carried off also from the equatorial regions, by currents of heated air ascending through the atmosphere, cooling as it expands, and passing along its upper surface towards the poles; while the air from the cooler regions passes over the earth's surface to supply the current. A large portion of caloric is dissipated also by radiation, and as the radiation increases in proportion to the excess of heat; it is one of the most powerful of the refrigerating causes that act in hot climates.

In cold climates the radiation from the earth during the winter season is smaller, and so is the counter radiation.

The interior part of the earth is very slowly affected by the changes of temperature that go on upon its surface, and appears to preserve a pretty uniform temperature of about 46° or 48° at a certain distance below the surface of all parts of the globe.

Captain Sabine found the temperature of the Caribbean sea, at the depth of 6000 feet, to be 45½°.

Section 4. *Contiguous Distribution of Caloric.*

Solid bodies conduct caloric by contiguity, in a slow gradual manner, and equally in every direction. As caloric accumulates in them they acquire the power of producing to our feelings the sensation of warmth. The more caloric is present in a body the hotter it feels. This feel-

ing we refer to temperature: but our sensations enable us to judge of temperature to a limited extent only. As heat or cold becomes extreme, an indistinct painful sensation is equally produced by either of them. A lump of frozen mercury placed in the warm hand produces nearly the same sensation as a lump of red-hot iron. Even in moderate temperatures our senses often lead us to judge incorrectly. When one hand is immersed into water, at the temperature of 40° Fahrenheit, and the other into water at 90° Fahrenheit; if both hands are then removed into water at the temperature of 65° Fahrenheit, it will feel warm to the one hand, and cold to the other.

It is of the utmost importance in various arts, as well as in science, to obtain the means of measuring, accurately, different temperatures. At this time great losses are frequently incurred from the want of an accurate measure of elevated temperatures, that can be applied with sufficient facility. The most usual and convenient thermometer, or measure of temperature, is an instrument founded on a property possessed, by bodies, of expanding in proportion to the heat applied, which will be explained more fully presently. Any convenient body may be used for this purpose. The most generally convenient seems to be mercury and atmospheric air. For very low temperatures pure alkohol seems best adapted, since it cannot be frozen unless by extreme cold; and for extremely elevated temperatures, air appears to be the most simple and convenient, as far as it can be applied.

When a glass bulb, having a long and fine capillary tube, the capacity of which is to that of the bulb as 1 to 40 or 50, is filled with pure mercury that is perfectly free from air and moisture, and hermetrically sealed while boiling,—it is capable of measuring temperature below the boiling point of the fluid to nearly its freezing point, provided a properly graduated scale be applied to the tube.

The scales of the thermometer are most usually graduated from the thawing point of ice,—a temperature which is the same all over the earth. As a second fixed point is necessary, a very convenient one is found in the temperature at which water boils, when the atmosphere presses upon its surface with a force which is about equal to that of thirty inches of mercury. When the respective elevations of the mercury in the tube, at these two temperatures, are marked, the space between them may be equally divided.

In the centigrade scale, which is the simplest, and in general use almost every where but in England; the space between the freezing and boiling point of water is divided into one hundred equal parts, called degrees, and these degrees or divisions are carried on equally upwards and downwards. It is numbered from its freezing point, which is called its zero. Thus, water is said to boil at 100 above zero. Mercury is said to boil at 350 such degrees above zero, and to freeze at about 40 such degrees below zero.

In the scale of Fahrenheit, which is that generally used in England, the space between the boiling and freezing of water is divided into 180 equal parts or degrees: but the zero, or supposed point of privation, is placed at 32 of these degrees below the freezing point of water. Thus, according to Fahrenheit's scale, water freezes at 32°, and boils at 212° above; while mercury freezes at 40° below zero, that is 72° below water, and is volatilized at about 662°. But the different parts of a thermometer tube are scarcely ever of an equal diameter; generally they are rather conical. Thermometers for delicate experiments, therefore, require an accurate measurement, in every part of their length.

The conducting power of different bodies, varies considerably. Generally speaking, the more dense bodies are, the better they conduct caloric. Thus, metals are gene-

rally the heaviest bodies, and the best conductors; but, on the other hand, platinum, which is the heaviest of the metals, is one of the worst of the metals as a conductor. Their conducting power, generally, is not proportionate to their density or weight.

When one of the ends of a number of rods of different metals of the same size, are dipped to a certain depth in melted wax, and the wax cooled; on heating the other ends equally, the softening of the wax will shew the rate, and extent of the conducting powers. Silver is the best of all conductors; at some distance comes gold, then copper, brass, iron, lead, zinc, tin, platinum. The most dense minerals follow these; then such as are more rare; bricks, pottery, china, ivory, bone, glass, porous woods, dense woods and charcoal. The conducting powers of woods are nearly inversely, as their specific gravity.

The want of a more perfect conducting power, their expansibility from heat, and consequent contractibility from cold, added to their brittle structures, are the reasons why cast-iron, glass, and earthenware, are so readily cracked by the sudden and partial application of heat, or cold, producing partial contractions and expansions.

Bodies feel hot or cold to the touch; not in proportion to their direct temperature, but in proportion to the quantity of heat they transmit in a given time. Porous wood, paper, or woollen, may be freely handled when at a temperature at which silver would burn us, or water scald. The relative conducting powers of bodies may, therefore, be judged of, to a certain extent, by the touch. When similar pieces of metal or wood, are heated or cooled to the same temperature, the metal will feel much hotter or colder than the wood; and the metal, which is the best conductor, will feel the hottest or coldest. If a piece of paper is held over a candle, it is singed immediately. The heat rapidly accumulates in consequence of the bad conducting

power of the air. If it be rolled tight round a cylinder of wood, the singeing of it is somewhat retarded. But if rolled tight round a cylinder of iron or of silver, it will be difficult to singe it before the metal also is heated.

The tongue is sometimes used to discriminate minute differences in the conducting power of bodies. Various precious stones are frequently distinguished by dealers, from spurious imitations in glass, in part from their superior power over glass, in conducting caloric.

On account of the slow conducting power of charcoal, it is sometimes used to surround stoves, for preventing the free transmission of caloric; but it requires particular care to keep it from the action of the atmospheric air, when at or near a red heat.

In consequence of the difference of conducting power between metals and ivory, or wood, it is usual to give handles of wood or ivory to metallic instruments, that are occasionally exposed to heat.

The breaking down of the cohesive texture of bodies, or rasping them, lessens the continuity of their texture, and consequently their conducting power. Metallic filings do not conduct caloric so well as the respective solid metals; nor saw-dust, so well as the wood it is obtained from.

The more air is entangled in the texture of bodies, the less they conduct heat. It would contribute much to the preservation of health, in variable climates, were more attention paid to the conducting power of the different materials employed in the manufacture of clothing, and of the fabrics constructed from them. Hemp and flax conduct more freely than silk; silk more freely than cotton; cotton than wool; and coarse wool than fine. In the manufactured materials, the lightest, finest, and thickest, are the warmest; the most dense, the coarsest, and the thinnest, are proportionally the coolest. A portion of air gets entangled in the interstices of light evenly-spun clothing, and

greatly improves its non-conducting power. It is retained there in part mechanically, and in part apparently by a degree of cohesive attraction between it and the fibres of the fabric. Count Rumford found that a thermometer which cooled a certain quantity in a given time, through an inch thick of air, when confined in a vessel, the heat being carried off by circulation, from a cause to be explained, was nearly twice as long cooling when a small quantity of fine lint was diffused through it, and much longer when the lint was exchanged for eider-down. To a certain extent as the quantity of eider-down was increased, the time of cooling was increased. But after a certain density was obtained, the conducting power was increased upon every addition of eider-down.

Air closely confined between two walls forms a very good non-conductor, for preserving ice-houses from internal heat, or stoves from external cold. A plate of air circulating round the walls of a heated flue, is a good defence from fire.

When the particles of a liquid body are, by any contrivance, kept in a quiescent state, while caloric is communicated through it, its conducting power is very slow and imperfect. Thus water stiffened with jelly, or apple pulp, or containing a portion of flocculent fibres to prevent a circulation of its particles, is a very bad conductor.

The particles of a pure liquid are readily moved among themselves by the slightest cause. When the particles contiguous to a heated body receive a portion of caloric they expand, become lighter than the rest, and rise through them. The particles that succeed to the place thus left, are, in their turn warmed expand rise upwards, and are succeeded by others. Thus, a circulation is established, and the heated particles carry away, and distribute the heat among those which are cold. This circulation is continued until the whole of the fluid is equally heated,

and then ceases. If a cold body be applied to the same part, to which the heat was formerly applied, a current is established in a contrary direction. In this manner fluids are heated, or cooled, in a very short time.

But so slow is the conducting power of a fluid, of water for instance, when no circulation takes place, that when a small quantity is frozen in the lower part of a long glass cylinder, that is nearly filled with cold water; by holding the upper part of the cylinder obliquely over the flame of a lamp, the water may be heated until it boils rapidly, without apparently affecting the ice. Place the ice at the surface, and it is liquified immediately.

When water is cooled to 39° or 40° Fahrenheit, its specific gravity, as we shall see, is greater than when at 32°, and consequently sinks in it. If water at 40° is poured upon ice, frozen in the tube, as in the last-mentioned experiment; a circulation of the warmer water downwards is produced, and more of the ice will be dissolved in a given time, than when the water is boiled.

This bad conducting power in water, in conjunction with the peculiarity of its expanding in bulk again, as it is cooled below 39°, is productive of very extensive consequences. In hot climates, the heat of the sunbeams falls with great force; the very slow conducting power of water confines the heat very nearly at the surface of the ocean where its accumulation is prevented, partly by radiation, and partly by the evaporation of hygrometric water that is constantly going on, to supply the increasing capacity of the heated air. In the polar regions, on the contrary, the rays of the sun, when present, fall very obliquely; and during a part of the winter are altogether absent. The supply of heat is small, and during the long winters is unequal to its dissipation. The water of the ocean is cooled at the surface, and sinks through the warmer water beneath in consequence of its increasing specific gravity. But when the

temperature of the ocean is cooled to about 40° or rather to 37°, which is probably the temperature of the greatest contraction in sea-water, all further circulation ceases, and the very slow conducting power of the water prevents any material portion of the heat from escaping from the ocean during the winter.

Low as the conducting power is of fluids in general, they vary among each other in this property.

It is still more difficult to ascertain the true conducting power of gasses, for not only do gasses, when partially heated, circulate more freely than water; but they transmit caloric with great freedom by radiation. When care is taken to prevent the communication of heat by radiation, and by circulation, gasses appear to be the most perfect of non-conductors.

The great difference there is between a close milled cloth, and a light one of the same weight; between any kind of wood and the saw-dust produced from it, depends upon the bad conducting power of the intermingled air.

A remarkable instance of the consequence of the slow conducting power of air, is recorded in the Philosophical Transactions of the London Royal Society.

Sir C. Blagden, Dr. G. Fordyce, and others, heated a small room, first to 212 Fahrenheit, and then to 240. They entered this room, spent a considerable time in it, and breathed the air, raised to this elevated temperature, without any great inconvenience. Their bodies, by their comparative coldness, condensed a portion of the hygrometric water. When they stood still, a cool stratum of air was produced around them, so that the heat of the room became less sensible than when they walked about. Their metallic buttons and watch-chains became too hot to be handled. An iron plate, which was placed in the room, became so hot as to boil a vessel full of water, which stood on it, and to boil an egg; a beef steak was cooked upon this plate, while they

were in the room. Iron heated to 120° is painful to handle; and water is scalding at 150°. It is easy then to understand that it would be impossible to exist in a temperature so elevated, were not the air an extremely slow conductor of caloric.

The conducting power of gasses appears to vary in a proportion which is nearly the inverse of their density. Sir H. Davy cooled a thermometer from 160° to 52° in equal confined volumes of the following gasses, in the periods annexed.

	Minutes.
Chlorine in	3.6″
Carbonic Acid	2.45″
Nitrous Oxide	2.30″
Atmospheric Air	2.
Oxygen	1.47″
Nitrogen	1.30″
Olefiant Gas	1.15″
Coal Gas	0.55″
Hydrogen	0.45″

Section 5. *On the Expansion of Bodies of Heat.*

As the temperature of bodies is raised, their density is diminished, they expand in bulk; consequently their specific gravity is lessened. This property is general, but it varies in different bodies.

The specific gravity of solids is less altered, by given increments of heat, than the specific gravity of liquids. The expansion of gasses is much greater than either.

When a bar of metal is heated, it becomes expanded in every direction; and the expansion increases as the temperature is elevated. The iron tires of carriage-wheels are

expanded by heating them. The circle is enlarged, and being applied to the wood work while hot, they contract as they cool, and embrace it firmly. Metallic bars and cylinders become longer and wider while they are heating, and while cooling they gradually contract to their former dimensions again.

The force with which this expansion and contraction takes place, is very great. The side walls of the Gallery at the Conservatoire des Arts et des Metiers at Paris, were forced outwards from their perpendicular, by the unequal pressure of the roof and floors. M. Molard, the engineer, restored them by the application of a number of strong iron bars, long enough to extend across the building and through both walls. Screws were cut at the ends of these bars, and furnished with plates and nuts. The alternate bars were then heated by means of lamps, and while thus elongated, the plates were screwed tight up. As they cooled the walls were brought nearer. The other set of bars were then heated, and screwed up in their turn. As they cooled the walls were further drawn towards the perpendicular, and the plates of the bars which were first heated, left projecting. By repeating this process, the walls were restored to their upright position; and retained there. This could not have been accomplished by any application of human strength.

There has been a great diversity of opinion, how far equal successive increments of caloric produce equal increments of expansion. The difficulty of elucidating this fact is great, because there can be no universal standard of measurement. The unequal variation of bodies must be measured by others equally liable to unequal variation.

In relation to solids, it appears from the most refined experiments that, as the temperature rises, the expansion produced by equal increments of temperature, is in a slowly

increasing proportion until they approach the temperature of their liquefaction; and then the expansion becomes irregular.

Different solids are expanded in different proportions, by similar increments of temperature. Each body has also its own peculiar rate of expansion.

It is of great importance in science, and in many practical arts, to obtain an accurate knowledge upon these points. Upon these properties are founded all our measures of temperature, all our thermometers, pyrometers, &c. In the construction of time-pieces, clocks, and watches, the contraction and elongation of the metals must be compensated.

In the construction of astronomical instruments also, the varying length of the materials of which they are constructed, requires consideration.

A variation in the length of a pendulum equal to one 3900th part, will cause a clock to vary from its true time as much as ten seconds in twenty-four hours. Great attention has, in consequence, been paid to this subject by different philosophers and artists; and various most ingenious contrivances and precautions have been applied to obtain correctness.

The most correct experiments on this point, appear to be those of Messrs. Dulong and Petit, according to which the following metals, when heated 180° — from 32° to 212° expand in bulk; copper $\frac{1}{194}$, iron $\frac{1}{282}$, platinum $\frac{1}{377}$.

But when they are heated three times 180°, that is, from 32° to 572°, the whole expansion produces an average for each third, or each 180° as follows. Copper $\frac{1}{177}$, iron $\frac{1}{277}$, platinum $\frac{1}{365}$.

Various contrivances have been had recourse to, for the compensation of these variations in particular cases. A pendulum of hard wood dried and varnished, is much less extended by heat than a metallic one. The gridiron pen-

dulum is formed of two metals of different expanding properties, which, by acting in opposite directions, preserve the length of the pendulum uniform. Another mode of preserving the uniform length of the pendulum, is to cause it to oscillate between bars of two unequally expanding metals rivetted together; and so adjusted as to bend downwards in the same proportion as the bar of the pendulum extends.

The following abstract shews the expansion in length of a bar of the respective solids produced by heating them, from 32° to 212°.

Length of a bar at 212°, the length of which at 32° is 1.00000.

Glass tube		1.00077	to 1.00086
plate		1.00089	to 1.100091
Crown glass		1.00080	
Deal		1.00081	
Platinum	from	1.00085	to 1.00099
Cast-iron		1.00111	
Steel	from	1.00120	to 1.00138
Iron	from	1.00115	to 1.00144
Gold	from	1.00146	to 1.00155
Copper	from	1.00171	to 1.00192
Brass	from	1.00178	to 1.00210
Silver	from	1.00189	to 1.00210
Tin	from	1.00217	to 1.00248
Pewter		1.00228	
Lead		1.00284	
Zinc	from	1.00291	to 1.00300

To obtain the expansion in volume, the above decimal quantities may be multiplied by three. Metals that have been condensed by previous mechanical force, expand more in proportion than those which have not.

Liquids expand, on the application of heat, in a much

greater proportion than solids. In their rates of expansion also, they differ more from each other.

The relative expansions of liquids may be measured by means of a glass bulb, with a long narrow neck. It may be filled to a certain mark with the liquid in question, and from thence the expansion produced by known increments of heat may be readily noted. The capacity of the bulb and of the tube must be accurately ascertained, and a proper allowance made for the increase of capacity produced by its increase of temperature.

Mercury at any temperature between 0° and 212° Fahrenheit, appears to expand in nearly equal proportions for equal increments of temperature. From that to its boiling point it expands in a slowly increasing proportion. Thus, when measured by an air thermometer, M. M. Dulong and Petit found that supposing the expansion of air to be uniform, the expansion of mercury between 0° and 100° of the centigrade thermometer is uniform, and correspond to that of air. When raised to 200° centigrade the mercury indicated 204°, and at 300° centigrade it indicated 314° 15′; thus shewing that, as the temperature rises, the proportionate expansion of mercury is slowly increased by equal increments of temperature. The absolute expansion of mercury, according to these philosophers, in raising the temperature from 32° to 212° Fahrenheit, is equal to $\frac{1}{55.5}$ of its bulk. In heating it from 212° to 392° it is $\frac{1}{54.45}$, and in raising it from 392° to 572° its increase of bulk is equal to $\frac{1}{53}$.

But when mercury is heated in a glass tube and bulb, the glass also expands, and thus the apparent expansion of the mercury is lessened. The apparent expansion of the mercury in glass for the first 180°, from 32° to 212°, is $\frac{1}{61.18}$; for the second to 392°, it is $\frac{1}{60.78}$; and for the third, to 572°, it is $\frac{1}{63.11}$ of its bulk. It is notwithstanding the most convenient body that can be used in a glass tube, as a thermometer, within a range extending from a few degrees above its freezing to

near its boiling point: that is, through a range of nearly 700° of Fahrenheit's degrees. For it happens that the expanding capacity of the glass is nearly in such proportion, as to counterbalance the increasing expansion of the mercury. As the temperature rises the proportionate increase of the mercury is indeed greater than is counterbalanced by the increasing expansion of the glass: but here another compensation offers itself. In all experiments where the bulb only is exposed to the temperature to be measured, the portion in the tube is not expanded; and this proportion increases as the temperature is raised. But in experiments upon temperatures above 300° Fahrenheit, where the tube also is immersed, an air thermometer is more correct.

The expansion of water is very irregular, its greatest density is at about 39°, as it cools below that temperature it expands. The same quantity of caloric that raises the temperature of water from 50° to 55°, will raise it from 122° to 128°, or from 200° to 207°. The total expansion of water, when heated from 39°, its state of greatest density, to 212°, is $\frac{1}{23}$ of its bulk. The expansion of sulphuric acid, for the same range, is about $\frac{1}{17}$. Linseed oil expands from 1.000 to about 1.027; alcohol from 1.000 to about 1.042.

Attempts have been made to explain the different expansions of different liquids, and the different expansions of the same liquid at different temperatures, according to some general law or laws: but hitherto without success.

In gasses, the same irregularities of expansion do not prevail. All permanently gaseous bodies, when separated, or insulated from the corresponding bodies in a liquid state, are equally and uniformly expanded by heat; that is, equal increments of temperature produce equal increments of expansion at every temperature, and in every gaseous fluid as far as the range of temperature has been examined.

It appears that one hundred parts of every gas that is permanently elastic at 32°, is expanded into 137.5 parts by

raising its temperature to 212°, or it is expanded $\frac{1}{480}$ part for every degree of temperature, as far as experiments have been carried. This law appears to extend to all bodies that are in the gaseous state, at whatever temperature they become so, under the usual atmospheric pressure.

The ventilation of rooms, houses, hospitals, and ships, is conveniently effected by taking advantage of this varying specific gravity, to favour the escape of heated, vitiated, or foul air, through openings in the ceiling and upper parts of buildings; corresponding openings being made at, or near, the floor for the admission of fresh air. Sometimes this circulation is increased by the help of lamps or stoves. In the ventilation of dwellings, in variable climates, the openings for this purpose should be commanded by moveable valves.

Hence is derived the superior value of air thermometers for measuring high temperatures, as well as minute variations of temperature.

Various means have been attempted for measuring very elevated temperatures, such as the temperature of furnaces.

Mr. Wedgewood constructed a pyrometer of clay, which was to mark the temperature of the furnace by the degree of contraction it underwent. For a time, great confidence was put in it: but, it cannot be depended upon; the pieces of clay sent from his manufactory, although, no doubt, prepared with every precaution, do not contract in equal proportion. Their contraction too is not in proportion to the temperature only; but also, to the length of time during which the temperature is applied.

According to Mr. Wedgewood's scale,—

	Fahrenheit.
The greatest heat of a blast-furnace is about .	32277°
Cast-iron melts at	17977
The greatest heat of a smith's forge	17327

	Fahrenheit.
The greatest welding heat of iron	13477
The least ditto	12777
Gold melts at	5347
Silver, at	4717
Swedish copper, at	4587
Brass, at	3807
Red heat, visible by day-light,	1077
Ditto, in the dark,	947
Evaporating temperature of mercury	600

Subsequent experiments show the evaporating temperature of mercury to be about 660° Fahrenheit.

It has been proposed to measure these elevated temperatures by the application of a horizontal bar of iron, or platinum, of which, a few inches of its length at one end, is turned at right angles, that it may dip, if necessary, into any vessel. A light metallic, or earthen, muffle, with a hole for the bar to pass through, must be applied at a certain distance. This bar should have cavities sunk into it, at regular distances from the extremity, into which thermometers, with a little oil or mercury, may be immersed. By means of these, the period that the bars take in heating or cooling, through a certain range of temperature, may be noted, and the temperature of the heated extremity inferred.

Mr. Daniel's thermometer consists of a bar of platinum inclosed in a tube of black-lead and earth. At one extremity the platinum is attached to an immoveable point: the other extremity communicates with a metallic thread, moving an index of a graduated circle, which is divided into 360 parts, or degrees, each of which is nearly equal to 5.58° Fahrenheit; or, more nearly, 17° of them are equal to 106° Fahrenheit.

According to this scale—

	Fahrenheit.
Mercury is said to boil at .	644°
Tin to fuse at	441
Bismuth, at	462
Lead, at	609
Zinc, at	648
Brass, at	1869
Silver, at	2233
Copper, at	2548
Gold, at	2590
Cast-iron, at	3479
A visible red heat	980
Common heat of an open fire .	1141

It has been proposed to apply, to the same purpose, an air-thermometer, the bulb, and part of the tube, being made of platinum, and surmounted with a bent glass tube, of an uniform diameter, and of a length sufficient to allow of an extensive range of temperature; and terminating in a recurvëd bulb; to retain a sufficient quantity of mercury to fill the tube, when the air is in its most condensed state. The expansion of dry air is in the proportion of three-eighths of its volume, for every 180° Fahrenheit. The tube must, of course, be long enough, and be graduated accordingly.

Section 6. *On the specific Capacities of Bodies for Heat.*

Different bodies are found to absorb very different proportions of heat, in passing from a lower to a more elevated temperature.

A pound of water, for instance, takes about 20.5 times as much heat to raise it any given number of degrees, as the same weight of mercury does; so that, if the precise quan-

tity of caloric that passes into water to raise its temperature 1°, should pass into mercury, it would be raised 20.5. When equal measures of the bodies are compared, as the specific gravity of mercury is to water, as 13.6 to 1; so the quantity of caloric, which raises a pint of water 2°, will raise a pint of mercury 3°. Accordingly, if a pint of mercury, heated to 100°, be mixed with a pint of water, heated to 50°, and well shaken together, the temperature of the two bodies will become 70°, and not 75°, the arithmetical mean. If, on the contrary, a pint of mercury, at 50°, be mixed with a pint of water, at 100°, the temperature of the bodies, after mixture, will become 80°. In the former case, the mercury loses 30°, and the water gains 20°; and in the latter case, the water loses 20°, and the mercury gains 30°.

Thus again, if one pound of oil, at 90°, be mixed with one pound of water, at 60°, the temperature of the bodies, after mixture, will become 70°: and if one pound of oil, at 60°, be mixed with one pound of water, at 90°, the temperature will become 80°. Whence it appears, that the oil loses twice as much temperature as the water gains, in one case; and gains twice as much as the water loses in the other. The capacity of water then to oil is, as 2 to 1.

Every body is therefore said, to have its own specific capacity, for caloric of temperature. Those bodies which take up the largest quantity of caloric, are said to have the greatest specific capacity. Tables of the supposed specific capacity of bodies are to be seen in almost every book of chemistry; but more recent and delicately conducted experiments shew that, for the most part, they are erroneous.

It appears that this specific capacity of bodies increases gradually as the temperature rises.

M. M. Petit and Dulong, by heating, with various precautions to ensure accuracy, a mass of iron to certain temperatures, and then transmitting the heat to water, found the specific capacity of this metal to be relatively, as follows:

The specific capacity of water being .1.

The average of its specific heat between—

32°	: and .	212°	. .	is	. .	0.1098
32	. . . .	392	. .	.	.	0.1150
32	. . . .	572	. .	.	. .	0.1218
32	. . . .	662	. .	.	. .	0.1255

On examining various other bodies, the same law was found to extend to them.

Thus the specific heat of—

Mercury, at 212°,	is	0.0330;	at 572°	0.0350
Zinc		0.0927	. . . .	0.1015
Antimony . . .		0.0507	. . . .	0.0549
Silver		0.0557	. . . .	0.0611
Copper		0.0949	. . . .	0.1013
Platinum		0.0314	. . . .	0.0355
Glass		0.1770	. . . .	0.1900

These philosophers pursued this subject to a considerable extent. By ascertaining the specific heat of a considerable number of bodies at 212°, and by multiplying them respectively by the calculated weight, or proportions of their supposed atoms, or prime equivalents, they demonstrated the existence of a law, which, if they are correct, is very curious and important: viz. that the atoms, or prime equivalents of all bodies have the same specific capacity; as may be seen from the following table;—

	Specific Heat. Water being 1.	Atoms. Oxygen being 1.	Produce.
Bismuth . .	0.0288	13.300	0.3830
Lead . . .	0.0293	12.950	0.3794
Gold . . .	0.0298	12.430	0.3701
Platinum . .	0.0314	11.160	0.3740

	Specific Heat. Water being 1.	Atoms. Oxygen being 1.	Produce.
Tin	0.0514	7.350	0.3779
Silver . . .	0.0557	6.750	0.3759
Zinc . . .	0.0927	4.030	0.3736
Tellurium .	0.0912	4.030	0.3675
Copper . .	0.0949	3.957	0.3755
Nickel . .	0.1035	3.690	0.3819
Iron . . .	0.1100	3.392	0.3731
Cobalt . .	0.1498	2.460	0.3685
Sulphur . .	0.1188	2.011	0.3780

The slight differences in the results may be considered as unavoidable errors in such delicate experiments.

Attempts have been made to find the specific capacities of gasses also, and their differences from each other. The specific capacity of the same gas varies as its density, or the pressure under which it is confined varies. It varies also with the temperature.

When a portion of gas is confined in a strong vessel, and heated, the temperature and the pressure both being increased together, the specific capacity is the result of the combined action of their forces.

When a gas, which is readily condensable into a liquid by pressure, is exposed to a high temperature, while confined over the liquid, its specific capacity is the result of still more complicated and varying forces.

The most correct experiments on this delicate subject, appear to be those of M. M. Delaroche and Berard, who have given us the following table, calculated at the natural temperature and pressure of the atmosphere.

	Equal Volumes.	Equal Weights.	Specific Gravity.
Atmospheric Air	1.0000	1.0000	1.0000
Hydrogen	0.9033	12.3400	0.0694
Oxygen	0.9765	0.8848	1.1111
Nitrogen	1.0000	1.0318	0.9722
Oxide of Nitrogen . . .	1.3503	0.8878	1.5277
Olefiant Gas	1.5530	1.5763	0.9722
Carbonic Oxide	1.0340	1.0805	0.9722
Cabonic Acid	1.2583	0.8280	1.5277

Or if the specific capacity of water be reckoned as unity, the specific capacity of

Atmospheric Air . .	is . .	0.2669
Hydrogen		3.2936
Carbonic Acid		0.2210
Oxygen		0.2361
Nitrogen		0.2751
Nitrous Oxide		0.2369
Olefiant Gas		0.4207
Carbonic Oxide Gas		0.2884
Steam		0.8470

In these experiments, the gasses contained hygrometric water.

According to the experiments of Mr. Haycraft, (Trans. Royal Society, Edinburgh, Vol. 10.) when atmospheric air, nitrogen, hydrogen, oxygen, carbonic acid, and carburetted hydrogen, are completely freed from vapour, their specific capacities in relation to their volumes are equal.

The experiments of Messrs. Clerment and Desormes upon this delicate subject, do not very essentially differ from the above.

The specific capacity of a gas increases with its density,

but in a much less proportion than its density increases. That is, when a given volume of gas is compressed with a double force, and thus reduced to half its former volume; consequently, to double its former density, its specific capacity in relation to its volume is increased; but in relation to its weight is diminished.

According to the experiments of M. M. Clement and Desormes, the specific capacity of equal volumes of atmospheric air of different densities when at the same temperature, is as follows:

	Inches.		
Atmospheric air under	39.6	of mercury	1.215
	29.84	. . . .	1.000
	14.92	. . . .	0.693
	7.44	. . . .	0.540
	3.74	. . . .	0.368

So that the density and consequent weight diminishes in the proportions 8.4.2.1: but the specific capacities diminish in a proportion which is less than 4.3.2.1.

The specific capacity of any given weight of gas lessens as its pressure, and consequent density is increased; and increases as its density is diminished. Hence, when a portion of confined air is suddenly pressed into a smaller space, the specific caloric; which it becomes incapable of retaining, appears in a sensible form; and elevates its temperature. On the contrary, when a part of the pressure is removed from a given quantity of gas, it becomes rarefied, its density is lessened; and although the specific caloric of a corresponding volume is less, yet the specific caloric of the whole volume is increased; and it rapidly absorbs caloric from surrounding bodies producing a sensation of cold.

Section 7. *On the Ratio of the Dissipation of Heat.*

Great pains have been taken to ascertain the rate of cooling among bodies. It has been thought that they must cool according to some general law; and that, if this law were discovered, it would enable the philosopher and the chemist to ascertain, from the time a body takes in cooling, the elevated temperature of such bodies as cannot be measured. This problem appears to be attended with too many difficulties, and to require too many precautions to be capable of practical application with any tolerable accuracy.

The rate of cooling of bodies is regulated by their temperature with relation to the bodies surrounding them, and the medium they are in;—the nature of their radiating surface;—the proportion of their conducting power;—the extent of surface exposed;—their power of reflecting and absorbing caloric;—their respective specific capacities;—and, in fluids, their carrying power.

In examining the ratio in which bodies are cooled, the heat which escapes by radiation should be distinguished and calculated, distinct from that which is expended in contiguous communication.

When a body is placed in the most perfect vacuum that can be procured, little heat is lost, except by radiation; and when the surfaces of two bodies, and their specific capacities are similar, it is most probable that their rate of cooling will be similar also.

M. M. Dulong and Petit placed a heated body in an exhausted balloon, surrounded with ice. Making an allowance, by calculation, for the imperfection of the vacuum, the following was the result:

A body heated to	240° centigr.	in 1 minute cooled 10°.7
	220	8 .8
	200	7 .4
	180	6 .1
	160	4 .9
	140	3 .9
	120	3 .
	100	2 .3
	80	1 .7

Whence it appears that when a body cools in a vacuum, surrounded by another body of a constant temperature; while the temperature falls in uniform progression, the radiation is diminished in nearly arithmetical progression. But the different specific capacities of bodies must very much affect the rate of cooling by radiation, as well as by contiguity. Numerous nicely conducted experiments by the same chemists, led them to conclude that the velocity with which a body cools, from the contact of a gas solely, depends on the density and temperature of the gas. But that, if the elasticity of the gas remains the same, the relative density and temperature may vary, without affecting the rate of cooling.

The heat that falls upon a body by radiation, must diminish in quantity as the square of the distance from the radiating body increases; although the experiments of some chemists appear to have led them to conclude it is in a greater proportion.

Section 8. *On the Zero or Point of Privation.*

Since, then, there are no means of depriving a body of the whole of its caloric, various philosophers have attempted to find, by experiment and calculation, how far bodies of a

given temperature may be from the real zero, or point of perfect privation of caloric. All attempts upon this subject have not merely proved vain, but have been attended with results which are contradictory and absurd, and which tend to shew that caloric, if it be, as is possible, a distinct element, is subjected to laws different from those imputed to matter. It has been supposed that this zero may be calculated from the difference which appears to take place in the specific capacity of a body, when it passes from a fluid to a solid state; by calculating the specific capacities of a body in each state, and ascertaining the quantity of caloric of temperature absorbed or evolved.

It has been attempted again, by measuring the quantity of caloric of temperature absorbed, or evolved in the mixture of certain bodies; and comparing it with the respective specific capacity of the bodies before and after mixture.

Dr. Irwine, from a comparison of the specific capacities of ice and water, estimated the caloric zero to be at 700° Fahrenheit below the freezing of water. Other chemists, from the same data, have estimated it at 1100° below the same point. Mr. Dalton, from mixing sulphuric acid and water in different proportions, calculates that it is, in one case, 6000°, in another 6400°, and in another 4150° below the freezing point of water.

From the mixture of nitric acid and lime, it has been placed as low as 11,000° from this point.

M. M. Lavoisier and Laplace made various experiments, from which it appeared to be at 3420°, at 7262°, and at 2598°, below 0° Fahrenheit, and, by a mixture of nitric acid and lime, they shewed that, if the principles upon which their calculation was founded were correct, the absolute 0°, or privation of heat must be at 23,837° above 0° Fahrenheit.

Section 9. *On Caloric of Liquefaction*

When the temperature of a solid body, of gold, for instance, or of lead, or ice, is gradually raised, as has been shewn, it gradually expands. Its cohesion is slightly affected, until it arrives at a certain temperature; then, if the application of caloric be continued, the body loses its cohesion of solidity, and becomes liquid. The temperature at which this change takes place is uniform, and peculiar to each body. It is called, in different cases, the thawing, the melting, the liquefying, the fusing, the congealing, the freezing, or the solidifying points.

It appears, at the same time, that while the body cannot support a higher temperature without being converted into a liquid, so it cannot become a liquid without causing to disappear, absorbing, or combining with, a certain large proportion of caloric. This caloric does not affect its temperature, nor can any part of it be removed, without restoring a proportionate part of the body to a solid state.

Thus, when a piece of ice at 32°, and an equal quantity of water at the same temperature, are placed in two vessels in a warm room, the temperature of the water will be affected immediately, and it will gradually rise to that of the room. The temperature of the ice at the same time will remain stationary, until the whole of it is dissolved; and then the water thus produced, will rise in temperature as in the preceding case. Or, place a lump of ice, cooled to 0° Fahrenheit, in a warm temperature, it gradually absorbs heat from the surrounding medium, and its temperature gradually rises to 32° Fahrenheit. It continues to absorb caloric at nearly the same rate, but the temperature remains stationary, and it becomes moist on the surface. As caloric is absorbed, the quantity of moisture increases, and at length the whole of the ice is con-

verted into a liquid, the temperature remaining at 32°. When all the ice is converted into water, its temperature again begins to rise, and continues gradually rising until it becomes of the temperature of the bodies around it. Now the caloric, it is clear, passes just as freely into the vessel during the dissolution of the ice, as it does before or afterwards: but it totally disappears, producing no effect on the temperature. As much heat has disappeared as would raise the temperature of the water 140°. Accordingly, if one pound of powdered ice at 32°, be mixed with one pound of water at 172°, the whole of the ice will be dissolved, and the temperature of the mixture will be reduced to 32°. But when water at 32° is substituted for ice, the temperature produced will be the arithmetical mean, or 102° Fahrenheit.

What has become of this caloric? Dr. Black, who first fixed the attention of philosophers upon this phenomenon, supposed that it combined with the ice as it passed into the state of water, and remained latent in it; and hence, that chemist applied to it the name *latent heat:* the more definite term of caloric of fluidity is now employed. It appears, that ice absorbs the same proportion of caloric whenever it passes into the state of water; but the precise part this caloric acts is not so clear.

It may be, as chemists have generally supposed, that water is a compound of caloric and ice in certain proportions. Upon this principle, it would be correct to consider all liquids as chemical compounds of respective solid bases and caloric. But there are phenomena which oppose this simple theory, even supposing caloric to be a distinct element.

It may be that, as the repulsive force, and consequent expansion of a solid, is increased by the increasing temperature, so far as to overcome its cohesive attraction, and convert it into a liquid; an increased capacity for caloric is coincident with its passage from the state of a solid to that

of a liquid; and, that the caloric which disappears, is attracted and absorbed to supply it.

Whatever is the nature of caloric, the phenomena in this case are simultaneous; the ice becomes fluid at the precise instant, and in the precise proportion, in which the caloric is absorbed.

The greater number of solid bodies are found to have the same property with ice, of being converted into liquids, when under the pressure of the atmosphere, by certain elevations of temperature; and, during the conversion, of absorbing a certain proportion of caloric.

Every body has its own specific temperature at which this change takes place; and during the change absorbs its own specific proportion of caloric.

Most bodies pass at once from the solid to the fluid state, without passing through any intermediate state of softness; but there are exceptions to this. Iron and platinum becomes soft before they are completely fused, and in this state different pieces are capable of being welded or hammered together: zinc becomes soft at a certain elevation of temperature, and capable of being rolled into lamine, or curved into cylinders; and at a little higher temperature, just below fusion, it may readily be granulated: tin may be granulated, or powdered in the same manner. Many animal and vegetable products, such as wax, fats, &c. soften before they become fluid. But most animal and vegetable fats consist of unequal mixtures of two bodies which are soluble at different temperatures, and separable by eliquation. Metallic alloys are sometimes separable in the same manner.

The following bodies are solid below the temperatures assigned them, as their liquefying points.—

	Fahrenheit.
Sulphuric Ether	—46°
Solution of Ammonia . . .	—46

	Fahrenheit.
Sulphuric Acid (sp. gr. 1.64)	—45
Ditto concentrated	—26
Nitric Acid, concentrated	—46
Ditto (sp. gr. 14.)	—30
Mercury	—39
Solution of Salt, saturated	+ 4
Ditto Sal Ammoniac	+ 8
Oil of Turpentine	+ 14
Strong Wine	+ 20
Common Vinegar	+ 28
Milk	+ 30
Water	32
Olive Oil	36
Tallow, about	100
Phosphorus	108
Spermaceti	112
Bees'-wax	142
Sulphur	226
Tin	442
Bismuth	476
Lead	612
Zinc	680
Antimony	809

When a solid is reduced to a fluid state by solution in a liquid, caloric is absorbed by virtue of the same principle. When a solid amalgam of lead, and a solid amalgam of bismuth are mixed, they have the property of becoming a fluid; caloric is absorbed during the liquefaction. Neutral salts, during their solution in water, or any menstruum, produce cold; and the degree of cold, although different in different cases, increases with the rapidity of the solution. When common salt and powdered ice or snow are mixed, solution

immediately commences, and the temperature of the mixture is lowered to the extent of 36° Fahrenheit.

Artificial cold, as it is called, is produced for experimental, or economical purposes, by the application of this property. But in producing very low temperatures by chemical solution, it must be recollected that the operator is limitted to those mixtures which are liquid at very low temperatures; for when a cooling mixture is reduced to its solidifying temperature, all further absorption of caloric ceases. The following table, abstracted from Mr. Walker's tables, shows the extent to which cold has been produced by chemical solution:

Mixtures.	Parts	Thermometer sinks.	Degree of cold produced.
Muriate of Ammonia	5		
Nitrate of Potash	5	From + 50° to + 10°	40°
Water	16		
Muriate of Ammonia	5		
Nitrate of Potash	5	From + 50° to + 4°	46°
Sulphate of Soda	8		
Water	16		
Nitrate of Ammonia	1	From + 50° to + 4°	46°
Water	1		
Sulphate of Soda	3	From + 50° to — 3°	53°
Diluted Nitric Acid	2		
Sulphate of Soda	6		
Muriate of Ammonia	4	From + 50° to — 10°	60°
Nitrate of Potash	2		
Diluted Nitric Acid	4		
Sulphate of Soda	8	From + 50° to 0°	50°
Muriatic Acid	5		

Mixtures.	Parts.	Thermometer sinks.	Degree of cold produced.
Snow or pounded Ice	2	From any temperature to -5°	—
Muriate of Soda	1		
Snow or pounded Ice	5	From any temperature to -12°	—
Muriate of Soda	2		
Muriate of Ammonia	1		
Snow	8	From $+32^{\circ}$ to -27°	59°
Muriatic Acid	5		
× Phosphate of Soda	9	From $+50^{\circ}$ to -21°	71°
Nitrate of Ammonia	6		
Diluted Nitric Acid	4		
× Snow	3	From $+32^{\circ}$ to -23°	55°
Diluted Sulphuric Acid	2		
× Snow	7	From $+32^{\circ}$ to -30°	62°
Diluted Nitric Acid	4		
× Snow	4	From 32° to -40°	72°
Muriate of Lime	5		
× Snow	2	From $+32^{\circ}$ to -50°	82°
Crystallized muriate of Lime	3		
× Snow	3	From $+32^{\circ}$ to -51°	83°
Potash	4		
Phosphate of Soda	5	From 0° to -34°	34°
× Nitrate Ammonia	3		
Nitric Acid	4		
Phosphate of Soda	3	From -34° to -50°	16°
× Nitrate of Ammonia	2		
Diluted mixed Acids	4		

These mixtures will produce a corresponding reduction of temperature at whatever temperature the ingredients may be mixed; provided the resulting solution is not cooled to its freezing point: then all further reduction ceases.

Those mixtures which are marked × have their freezing point very low, and therefore may be combined at a previously reduced temperature for the production of extreme degrees of cold.

Bodies which are liquefied or fused by elevation of temperature, are, as may be expected, rendered solid again by lowering it in a corresponding degree; and the solidifying point of temperature is the same as that of liquefaction in the former case. In returning to the solid state, they evolve again the same quantity of caloric that disappeared during liquefaction.

When the cooling of a liquid, of water for instance, is very slow, and in a state of perfect rest, exposed to little light, the water may be cooled 5° or 6°, 10°, or even 20° below its freezing point, still continuing fluid. But upon the slightest agitation of the particles of the liquid among themselves, crystallization will commence in several points, and the crystalline spiculæ will extend suddenly, or shoot in various directions, the temperature rising simultaneously and suddenly to 32°, at which temperature it will continue until the whole of the water be frozen; then it gradually falls to the temperature of the medium it is placed in. Saline solutions, during their crystallization, evolve caloric; and may, by similar management, be cooled considerably below the temperature at which they become saturated, before crystallization commences. In the crystallization of some metals, the same phenomena appear to take place, but in a lesser degree.

During the act of solidifying, many bodies are contracted in bulk; some suffer little apparent change; and some

are expanded. The expansion of cast-iron during its solidification renders it so valuable for receiving ornamental impressions on its surface; and consequently extends its application to many useful and ornamental purposes. The same property of antimony renders it a valuable ingredient in type metal. Without it printing would not receive that clear and neat sharpness, which renders it so beautiful. Water possesses this property in a remarkable degree: in crystallizing it expands $\frac{1}{10}$ in bulk.

Water possesses also the property of expanding as it cools, when its temperature has approached within a certain distance of its freezing point: that is, water contracts pretty uniformly until its temperature is lowered to about 40° Fahrenheit. It then expands in an equal gradation to its freezing point. There is no small difficulty in finding the precise point of temperature at which water is at its greatest density. Many chemists have examined this point; but the question is not as yet precisely decided. When the French Government regulated anew their standard of weights and measures, the greatest density of water was assumed at 40° Fahrenheit, and this approximation appears to be near enough for practical use. From this water expands in cooling to 32° in exactly the same proportion that it expands for a corresponding increment of temperature; thus, suppose a mass of water at 40° Fahrenheit be considered of 100000 parts by measure,

at	39°	and at	41° it expands to 100001
	38		42 100002
	37		43 100003
	36		44 100004
	35		45 100005
	34		46 100007
	33		47 100010
	32		48 100012

When water is cooled without freezing to 26°, it is found that the rate of expansion continues.

It appears that this property is not confined to water. Most probably it extends to all those bodies that expand as they become solid. This property in water, as well as its imperfect conducting power, is productive of extensive, and important consequences in hydrology. The waters of the ocean are at their greatest density at a temperature which is several degrees above their freezing point. Water at a temperature much above or below 40°, cannot descend into its depths, nor can the caloric be increased or abstracted but by a very slow tedious communication. The temperature is therefore preserved very equable, whatever may be the varying temperature of the surface. Were the specific gravity of water and ice, like that of lead or mercury, to continue increasing as the temperature falls, all lakes in high polar latitudes; and even the ocean, would soon be converted into solid ice, which the short summers of those latitudes would never again thaw. Now, in the polar regions the ice is confined to or near the surface.

Bodies that expand in volume in passing out of the liquid into the solid state, expand with such force as to overcome any resistance that may be opposed. Bottles that are full of water are always broken by the freezing of the water; water-pipes full of water, whether of lead, or of cast-iron, share the same fate. A cast-iron bomb-shell filled with water and plugged, is burst by converting the water into ice. Hard turnpike or gravel roads, if frozen while wet, are completely broken up; porous earthen vessels, flower-pots, &c. if frozen while the pores are filled with water, are destroyed: and in the same way, hard stiff clayey soils are disintegrated.

All solids do not pass into a liquid state upon elevating their temperature; some pass at once into the state of

gas. Thus, iodine, benzoic acid, carbonate and muriate of ammonia, at a moderate heat, are converted into gasses or vapours, which, on cooling, are condensed into dry crystalline solids.

Section 10. *On Caloric of Vaporization.*

When a liquid is exposed to a gradually increasing temperature, under atmospheric pressure, it expands progressively, as the temperature rises.

At a certain further elevation of temperature, it suffers a change, and is converted into an intangible elastic fluid, or gas. The body undergoes a prodigious increase of volume, and a large quantity of caloric is absorbed.

The temperature necessary to produce this change, the quantity of expansion produced, and the quantity of caloric that is absorbed, are peculiar to each different body. They are regulated also by the atmospheric pressure upon the surface.

The vaporization of water affords a good specimen of the manner in which all other fluids are vaporized. When a vessel full of water is placed over the fire, or over a burning lamp in the open air, the caloric passes in through the bottom, and the water is gradually heated until the temperature arrives at 212°. At first a circulation takes place in the liquid, from the continued change of specific gravity produced, through the unequal application of heat. A quantity of gas that is combined with the water in part, is set free; as the water becomes heated a part of it is converted into vapour at the bottom, and is again condensed by the cool liquid above it as it ascends through it; producing the hissing or singing as it is called. The agitation thus produced continues increasing until the water is heated throughout to the boiling temperature, when the vapour

escapes from the water uncondensed. Then the water is said to boil. Now occurs the same phenomenon which appeared during the liquefaction of ice; the temperature becomes stationary, although the caloric continues passing in; but the water continues boiling as long as heat is applied.

When the water is placed in a shallow vessel, and the caloric applied chiefly to the upper surface, the vaporization is produced without boiling; the temperature remaining stationary as before, until the whole of the liquid is converted into gas or vapour.

During this process, as much caloric is absorbed as would have raised the temperature of the water, could it have remained in a liquid state; 970° nearly; yet the temperature of the vapour, like that of the water it is produced from, is 212°. If the vapour be retained in a proper vessel, and the application of heat continued, its temperature will progressively rise, as that of the liquid did before the vaporization began.

If a gallon of water be thus converted into steam at 212°, and again condensed, by passing it into ten gallons of water at 60°, the usual atmospheric temperature, it will raise its temperature 97°; that is, from 60° to 157° nearly. Now, $97° \times 10 = 970°$ = the quantity of caloric absorbed during the conversion of the water into gas. So that the whole of the caloric that is absorbed during the conversion of the water into gas, is again given out during the condensation of the gas into water.

When water is evaporated by boiling in open air, an opaque steam appears to arise from the surface of it. This is produced by the cold atmospheric air mixing with the vapour, and condensing it into minute particles of water, as soon as it has escaped from the boiling liquid. Pure vapour is perfectly transparent, and continues an uncondensable elastic fluid, as long as its temperature and pressure continue unchanged.

Under the same atmospheric pressure, different liquids are converted into vapour at different temperatures. Thus, under a pressure equal to thirty inches of mercury:

	Fahrt.		
Water is vaporized at	212°	Oil of Turpentine about . .	200° to 210°
Ether	96	Sulphur	554
Alcohol	174	Mercury	662

If the atmospheric pressure upon these liquids could be wholly removed; that is, if they could be exposed in a perfect vacuum, they would boil, or be vaporised at a much lower temperature; according to Dr. Robertson at 145° lower. Water, in that case, would boil at 65°; alcohol and ether would be gasses at the freezing point of water. When the pressure of the atmosphere is lessened, as it is in ascending lofty mountains, or by producing a partial vacuum, the boiling temperature of liquids is proportionally lowered. Water, therefore, boils at a lower temperature in the garret of a house than in the kitchen; on one day, when the barometer is low, than on the next when the barometer has risen.

When the pressure upon the surface of a liquid is increased, its boiling temperature is proportionally raised. The temperature, indeed, at which water boils at any particular place, varies with the height of the barometer. On the summit of Mount Blanc, water was found to boil at 187°. Thus, when the barometer stands at

26	inches, water boils at	204°.9
27	. . . . .	206 .67
28	. . . . .	208 .43
29	. . . . .	210 .2
30	. . . . .	212 .
31	. . . . .	213 .76

When water is boiled in a deep vessel, it is reasonable to expect a difference of temperature to be produced between the upper and lower part of the liquid, proportionate to the difference of pressure. But a difference of temperature is observed, which is connected with the material of which the vessel is constructed; and appears to be produced by the difference of attraction which may exist between the vessel and the fluid. M. Guy-Lussac found that water boiled in a vessel of tin-plate at 212°, while it boiled at 214° under the same pressure in a glass bulb.

The ebullition of water in glass is very irregular, and that of some other liquids, of sulphuric acid, for instance, is still more so, frequently causing a fracture of the vessel. This phenomenon appears to arise from the same cause acting with more force, for the less the capacity for heat may be in the vapour, the more rapidly it is produced.

In the conversion of a body into the gaseous state, its volume is prodigiously increased. A cubic inch of water, for instance, produces, at the usual atmospheric pressure, nearly a cubic foot of steam. Or, according to M. Guy-Lussac, it expands into 1694 cubic inches: the specific gravity is, consequently, lessened in an inverse proportion. Gases, or vapours, become very elastic also. If not confined, they would expand into free space, until their further expansion were restrained by their gravitating attraction.

This is extensively exemplified in our atmosphere; the lower part, with which we are surrounded, is very dense; but as the distance from the earth's general surface increases, the pressure abates in a rapid ratio. So that, on the top of the most lofty mountains, the air is scarcely sufficiently dense to support animal life. The upper surface, having no superincumbent pressure, can have nothing to counterbalance its elasticity, and to restrain it from spreading out into free space, but its gravitating attraction. Its

rarity must, therefore, be very great; but if matter, as is supposed, consist of distinct solid atoms, it may be, and indeed has been, subjected to calculation.

The attraction between the atoms of liquids is, generally speaking, slight, and is supported by a balance between their temperature, and the pressure that is made upon their surfaces. Were the pressure of the atmosphere removed, many bodies would cease to exist as liquids; and at a certain elevation of temperature, would pass at once from a solid to a gas. Even water would be fluid through the range of a few degrees only; and be converted into gas at the common atmospheric temperature.

This is readily exemplified, by placing a vessel of water, a slice of meat, or of any solid substance, saturated with water, in the receiver of an air-pump; upon exhausting the receiver of air, it is immediately filled with the vapour of water, of a density that is proportionate to the temperature. This forms a new atmosphere, which, by its pressure upon the surface of the liquid, prevents any further vaporization. But, if a vessel, containing sulphuric acid, muriate of lime, or any substance that has a strong attraction for the vapour of water, be introduced into the receiver, the vapour, as it comes in contact with the surface of it, is absorbed. Thus a partial vacuum is preserved, and the vaporization of the water continues, until the whole is converted into vapour; and transferred, by successive attraction and condensation, to the attracting substance.

The vapour during this process, attracts caloric from the water, and surrounding bodies; and a corresponding degree of cold is produced. An apparatus of this kind was recommended by Mr. Leslie for drying substances, and for procuring the evaporation of liquids at low temperatures, in various chemical processes. Distilling vessels are now constructed on the same principle, to carry on their opera-

tions at low temperatures. The cavity of the still and of its receiver, must be rendered air-tight; and then, in proportion as it is more completely exhausted, the distillatory or evaporating process may be carried on with a more gentle heat: the receiver being at the same time kept cool by surrounding it with ice.

As, during the liquefaction of ice, the water formed, notwithstanding the large proportion of caloric it absorbs, is of the same temperature as the ice; so, during the vaporization of water in a confined vessel, the vapour formed is of the same temperature as the water it is formed over. As the vaporific point of the water is raised by increasing the pressure on its surface, the temperature of the vapour rises with it, and its density increases.

Vapours when uncondensable into liquids, are gasses, and consequently subject to the same laws; their elasticity being increased in the same proportion from elevation of temperature, or increase of pressure; but when confined over their respective liquids they are differently circumstanced, and the elastic force of the vapour is modified, it being susceptible of the liquid state under a temperature varying with the pressure.

The elastic force of vapour, and consequently its power of overcoming pressure, increases in a much more rapid ratio than the increasing temperature. When water is confined in a strong vessel, by a variable column of mercury, its increasing elastic force, in proportion to its temperature, may readily be measured. Thus, according to Mr. Southern, at 212° water is converted into vapour under the pressure of one atmosphere equal to a column of mercury 29.8 inches high, or, as fluids press equally in all directions, equal to 15lbs. upon each square inch of the surface of the confining vessel. When the temperature is raised to 250.3, its elasticity is sufficient to overcome the pressure of two atmospheres, or 59.6 inches of mercury; and it exerts a force

equal to 30lbs. upon each square inch of the surface of the vessel which confines it. A further addition of 43°.1′ of temperature, making it 293°.4′, doubles its force again. It will now overcome a pressure equal to four atmospheres, or 120° inches of mercury; and will press upon the sides of the containing vessel with the force of 60lbs. upon each square inch of its surface. When the temperature is increased about 50° more, that is, to 343.6, the elastic force is again doubled. It exerts a force equal to eight atmospheres, or to a column of mercury 238.4 inches high, or equal to 120lbs. upon each square inch of surface.

The following table is abstracted from the experiments of Mr. Taylor on the same subject, and shews the force that steam exerts (besides overcoming the pressure of the atmosphere,) in proportion to its elevation of temperature.

Steam heated to	Supports a column of mercury equal to	
220	4.95 inches	
230	11.51	
240	20.	
250	29.12	about 1 atmosphere
260	40.10	
270	52.5	
280	67.75	
290	84.5	
293.4	90.4	above 3 atmospheres
300	103.75	
320	149	about 5 atmospheres.

The Royal Academy of Paris have lately been applied to by the French Government, to point out the proper means to prevent accident from the bursting of steam boilers. They have, in consequence, published a table of the relative

force and temperature of steam, which they consider as *nearly* correct. It nearly coincides with Mr. Taylor's.

These approximations are the result of actual experiment; and it is most probable that, by raising the temperature to 400°, the elastic force or tendency to burst the vessel, would become equal to the enormous force of 250lbs. upon every square inch of its surface. The extreme danger, then, from overloading the valves of the best constructed steam boilers, may be easily appreciated. This danger is increased, not only from the necessary action of the caloric and oxygen upon the bottom of the vessel; but also from the property that metal has, of becoming weaker, as its temperature is raised.

If a vessel were procured of sufficient strength to resist the elastic force, and an operator found fool-hardy enough to use it, there is no doubt but that water, as well as iron, may be heated red-hot. The following abstract of a table, formed by Dr. Ure, and published in the Philosophical Transactions, shews the elastic force of the vapour of water from 8° below its freezing point to 312°, when it boils under a pressure equal to $5\frac{1}{2}$ atmospheres. If correct, it shews the force of steam to be still greater than the foregoing experiments represent it to be.

Table of the elastic force of the vapour of water, in inches of mercury.

Temperat.	Force. Inches.	Temperat.	Force. Inches.
24°	0.170	90	1.360
32	0.200	100	1.860
40	0.250	110	2.456
50	0.360	120	3.300
60	0.516	130	4.366
70	0.726	140	5.770
80	1.010	150	7.530

Temperat.	Force. Inches.	Temperat.	Force. Inches.
160	9.600	260	72.300
170	12.050	270	86.300
180	15.160	280	101.900
190	19.000	290	120.150
200	23.600	300	139.700
210	28.800	310	161.300
212	30.000	311.4	164.800
220	35.540	312.	167.000
225	39.110		
230	42.100	Another Experiment.	
240	51.700		
250	61.900	312	165.500

The rapidly increasing force of steam, in proportion to its increasing temperature, suggested the use of high-pressure steam engines. They are found to be less expensive in their construction, and a greater disposable force is obtained, as may be expected, in proportion to the fuel consumed.

Water converted into vapour under any given pressure, may be reconverted into a liquid state by increasing the pressure: the latent caloric previously absorbed, at the same time becoming sensible.

Every fluid has its peculiar boiling or vaporific temperature, and its peculiar ratio of expansion and density, at different temperatures.

In all cases of converting solids into vapours, or gasses, a large quantity of sensible caloric is absorbed; as has been explained in the instance of water. Such bodies as are extremely volatile, and, consequently, evaporate rapidly on exposure to air, are frequently used for the temporary production of cold. Dip a thermometer, covered with a bit of linen or cotton, into alkohol or ether, and hold it in the air, the temperature will fall several degrees, but most in the latter case, because the ether is most volatile. Place a

thin tube of water in a glass of ether, under the receiver of the air-pump; on rapidly exhausting the air, the ether will boil, and abstract so much caloric from the water, during its evaporation, as to freeze it. Mercury, by a little management, may be frozen in a similar manner. When, instead of ether, carburet of sulphur, or sulphurous acid, condensed into the liquid state, are used, still more intense cold is produced.

Attempts have been made to investigate the quantities of caloric absorbed by different bodies, in their change into the gaseous state; but, in most cases, this is attended with great difficulty, and the results of the experiments of different chemists do not agree.

The quantities of caloric absorbed by certain bodies, during their conversion into vapours, according to the experiments of Dr. Ure, are as follows:

During the change of water at 212° into vapour,			976°
Alkohol, sp. gr.	825 at	173	442
Sulphuric ether		104	302.4
Petroleum Oil of Turpentine			177.9
Nitric acid, sp. gr.	1.494 at	165	532
Liquid ammonia	0.978		837.3
Vinegar	1.007		875

When a vapour, the vapour of water for instance, passes into a cold medium, it is condensed, and the caloric again given out. In this manner, one gallon of water converted into steam, at 212°, will communicate nearly 6½ times as much caloric as a gallon of water at the same temperature. This affords a very useful, safe, and economical way of transporting and communicating heat in various arts; and for various economical and domestic uses, where the temperature required does not exceed 212°.

Supposing, therefore, water were heated to 700° Fahrenheit, under a sufficient pressure, and then the pressure discharged, about half of it would instantly burst forth into the atmosphere with great force, and be converted into vapour at 212° Fahrenheit: and the remainder of the water would be reduced to the same temperature.

In fitting up boilers for producing steam, the surface exposed to the heat should bear a due proportion to the quantity of steam required, and to the time or rapidity with which it is required.

The density of vapour increases nearly in the same proportion as its pressure. A cubic foot of steam, at 212° under the atmospheric pressure, contains 1.04 cubic inches of water. According to Mr. Southern's experiments, a cubic foot of steam, under the pressure of 40 inches of mercury, contains about 1.43 inches; under a pressure of 80 inches of mercury, it contains 2.94; and under a pressure of 120 inches, it contains 4.28 cubic inches of water.

The capacity for caloric of a given weight of steam, diminishes as its density is increased. Water distilled by Mr. Watt at a low temperature and pressure, absorbed between 120° and 1300° of caloric, while under the atmospheric pressure, it does not absorb more than 976°. When a gas, or vapour, that is under a given pressure, is suddenly rarefied, by enlarging the cavity containing it, considerable cold is produced; a quantity of caloric being instantly absorbed, to supply the demand produced by its increased capacity. When, on the other hand, it is condensed into a smaller space, its capacity is diminished, and a quantity of caloric evolved; by suddenly condensing into $\frac{1}{4}$ of its volume, a portion of air, confined in a tube, a red heat may be produced, and tinder ignited. If a quantity of steam, of a sufficiently high temperature to prevent its liquefaction, be suddenly condensed into half its volume, its density, and its elastic force will be doubled. Its temperature

will be considerably elevated by the caloric evolved, in consequence of its diminished capacity, and its elastic force will be further increased, in a certain ratio proportionate to the elevation of temperature. Various experiments shew, that the same law extends to high temperatures, as well as to low.

The consequence of this change of capacity is that corresponding weights of steam at different densities give out, upon condensing into water, nearly the same quantities of caloric. Thus, according to Mr. Southern's experiments, a certain weight of steam

At 229° under 40 inches, gave 942:
At 270 80 . . . . 942:
At 295 120 . . . . 950. The recent experiments of M. M. Clemont and Desormes confirm this fact. A tube from a steam boiler was inserted into a vessel of water; when a certain quantity of steam had entered, the temperature was noted. The steam was heated until its elasticity was doubled; and then passed into the same quantity of water, until the same quantity of steam had passed. A third experiment was made, by raising the temperature of the steam, until its elasticity was equal to three atmospheres. As much steam was allowed to pass as raised the water to the same mark as in the two former experiments; the temperature produced was the same in all three cases. The knowledge of this fact is of great consequence to the makers of steam-engines, especially of those to be worked under a high pressure, and an attention to it has been productive occasionally of great disappointment and loss.

A remarkable instance of the increasing capacity of steam for caloric during its sudden expansion may be observed in the generator of Mr. Perkins's steam-engine, which has lately attracted the public attention. The boiler is small and kept full of water at a temperature of nearly

500°. Its elasticity therefore, or tendency to expand into vapour, is exerted with very great force. Upon raising the valve a portion of the heated water is liberated, and flies out in the state of a dense steam. During its expansion it attracts caloric with great force from the colder bodies it comes in contact with; and notwithstanding its elevated temperature, as it issues from the boiler, it produces a sensation of cold, to the hand applied near the orifice; while at a short distance, where the expansion is completed, it is scalding hot: and yet at this part its real temperature must be much lower, in consequence of its having absorbed a considerable part of its own sensible caloric, to supply the demand produced by the increased capacity.

When a vapour is insulated from its respective liquid and is at a sufficiently elevated temperature to prevent its condensation, it may be considered as a permanently elastic gas, and is subject to the same laws.

The curious experiments of M. Cagniard de la Tour, shew that a fluid cannot be converted into a highly compressed vapour or gas, unless a certain additional space be allowed. Thus, a portion of ether at a sufficiently elevated temperature is converted into a gas that, under a pressure of 37 or 38 atmospheres, occupies a space equal to double its volume as a liquid.

Alcohol gas compressed in the same manner, the temperature at the same time being sufficiently elevated, was compressed into a space equal to three volumes of the liquid. The pressure required was equal to about 117 or 119 atmospheres.

Water vapour or gas was compressed into a space equal to four volumes of the original water, by a pressure equal to about 480 atmospheres.

In all these cases every attempt to force these gasses into less space, condensed them into liquids. No elevation of temperature, that could be applied, prevented it. In the

last experiment, the requisite temperature was rather below the melting point of zinc.

We commonly consider that state to be natural to a body, in which we find it under the atmospheric pressure, at the temperature in which we are living. Any change produced under a varied pressure, or temperature, we are apt to consider as a forced state. Oxygen, therefore, hydrogen, carbonic acid, chlorine, sulphurous acid, and a variety of other bodies, we consider to be natural gasses. Water, alcohol, ether, essential oils, &c. we consider as being naturally liquids; and we consider gold, lead, iron, tin, wax, spermaceti, and even butter, as being naturally solids. It appears, however, that these different states are equally natural to all bodies, and depend upon the temperature they are existing under. The greater number of the bodies we are acquainted with, we know to be susceptible of all these states, at different temperatures, from the wonderful action of caloric. There is the strongest analogy to support the conclusion, that the apparent exceptions are the consequence of our limited power over temperature. Bodies in this respect differ merely in relation to the temperature at which the changes take place. Every body, whether simple or compound, has its own specific temperature of liquefaction, or gassifaction; but, could every body be deprived of caloric, there is little doubt but that the natural state would be that of a solid.

Of the bodies apprehended to be simple material elements, only four are considered as gasses: oxygen, hydrogen, nitrogen, and chlorine. The latter of these, the recent experiments of Davy and Faraday shew, is easily compressed and cooled into a solid; the other three gasses are uncondensable by any cold or pressure that has yet been applied; but they are all readily solidified by chemical combination.

On the other hand, raise the temperature a little, and

butter and lard become fluids;—a little more, and ether becomes a gas—a fluid that is permanently elastic, as long as the temperature and pressure are unchanged. As the temperature becomes elevated, spermaceti, suet, wax, become fluid like oils; alkohol, phosphorus, sulphur, water, arsènic, zinc, and at length even silver, gold, and platinum, are converted into gasses. And let it be observed, they are no more temporary vapours than other gasses are; they are permanently elastic under the temperature and pressure at which they are formed.

The term vapour, then, should be understood as applicable to a gas that is produced at a temperature comparatively elevated, and is consequently condensable into a solid or liquid by a moderate pressure, or a slight depression of temperature.

In relation to gaseous bodies, pressure and temperature may be considered as opposing forces. The more the temperature of a gas is elevated, the greater is the pressure requisite to condense it; the lower its temperature, the less pressure will condense it. In all attempts to compress the hitherto uncondensable gasses, these two laws must be made to co-operate. In a given temperature, the density and elastic force of a gas is as the pressure that confines it. Thus, for instance, four feet of atmospheric air, confined by a pressure equal to 7½ inches of mercury, becomes two feet when pressed with a force equal to 15 inches; and one foot, when pressed by a force equal to 30 inches. If the pressure be increased to 60 inches, its volume is reduced to half a cubic foot; and if the pressure be again doubled, it is reduced to ¼ of a cubic foot, or 432 cubic inches, its elastic force being equal to the pressure made upon it, provided its temperature be stationary. During this experiment, however, in consequence of the diminishing capacity of the gas, a quantity of caloric is evolved, and, if time be allowed, is gradually dissipated.

The same law that is called into action during the vaporization of water, and of the bodies that have been named, acts in every case of vaporization whatever.

Bodies that have the property of escaping into the air when exposed to it, by what is called spontaneous evaporation,—all volatile and odoriferous bodies are converted into gasses, and absorb caloric.

DIVISION IV.

MATERIAL CHEMICAL ELEMENTS.

Part 1. Remarks on Chemical Attractions generally.

The bodies that surround us are not, as we have seen, in their simple uncombined state. They are mixed together or combined, according to the mechanical and chemical forces they have the power of exerting over each other. To the chemical forces that bodies exert over each other, the name Chemical Attraction is given. The laws that govern these forces, are general and invariable; and the effects of them are consequently equally invariable under similar circumstances.

These laws it is the business of chemistry to unfold. But in addition to the wonderful agencies already pointed out, and which extend their influence over all matter; there are other agencies which extend their influence in certain cases only.

Animal and vegetable life has an extensive power over chemical attractions. They suspend them and vary them, and turn them so as to produce an immense number of compounds adapted to their final purpose, in a manner unknown to us, and inimitable by us. Hence are produced all the varieties of animal and vegetable bodies; the greater part of which consist of compounds that would not have been produced by simple chemical action, and cannot be imitated by art.

When an animal or vegetable dies, the different parts of

its body again return under the laws of chemical attraction; and, according to the influence of these laws over them, they are sooner or later resolved into their elements, or into compounds more strictly chemical. The consideration of the bodies must be deferred until we have explained the laws and properties of inorganic matter.

When two homogeneous bodies, two portions of water, of alkohol, of a fused metal, or of any solids reduced to powder, are mixed; whatever action or attraction may take place between them, or their respective particles; must be considered as purely mechanical. The properties of the atoms or elementary particles must continue unchanged. When any two heterogeneous bodies are mixed, as oil and water for instance; if no action follows that produces some alteration in the properties of the minute atoms or particles of the respective bodies, the forces that retain them together, in the same manner are purely mechanical. But if, on the admixture of two different bodies, the smallest change appears to be produced in all, or any of the properties of their respective ultimate particles; if there be a slight evolution or absorption of caloric for instance: or a deviation from the medium of specific gravity; a dissolution of a solid in a fluid; of a lump of sugar, or of salt, for instance, in water; it is considered as indicative of chemical attraction.

Of the cause or causes of the various chemical attractions, no more is known than of the cause of gravitation. The various properties of the different kinds of matter appear to be impressed in them by the fiat of the Creator, to fit them for their respective places and uses in the creation.

By pursuing the laws of chemical attraction, and the changes they produce; the chemist is able to discover the chemical nature of bodies, and to separate them; that is, to analyse them. With certain limitations, he is able to prove the correctness of his analysis by synthetically reproducing their resemblances.

Chemical attraction is a force which acts between the elementary atoms or particles of bodies. But to render this axiom intelligible, the term, elementary atom, must be explained, and its meaning limited. It has already been observed, that we know nothing of the element, or elements called matter, considered abstractedly. Our knowledge of it extends only to certain of its properties when collected in masses. We must be content to consider provisionally, those bodies which the chemist has not decomposed as distinct elements; and, in the present state of chemical knowledge, it is extremely convenient to use a definite language, and to speak of them as being constituted of extremely minute, indivisible, and, therefore, elementary atoms: the metals, for instance, are considered as simple elements. But it may be, that gold is compounded in a way not understood, of two or more primary elements. If so, its elementary atoms, it would appear, must have a definite magnitude; and would be decomposed or destroyed by division. At the same time, it does not appear that any primary, or even secondary element, has ever been decomposed by mechanical division.

Bodies produced by the union of two primary chemical elements, may be considered as secondary elements, and having their ultimate indivisible atoms in the limited sense the primary have; for two of these secondary elements may unite and form a secondary compound; which may, in its turn, assist in producing a ternary compound. Thus, sulphur and oxygen produce sulphuric acid; sodium and oxygen produce soda. These two compounds, when mixed in a certain proportion, produce a salt called sulphate of soda. The proximate elements, then, of sulphate of soda, are the compounds sulphuric acid and soda; while the primary chemical elements, are the remote or ultimate elements of this compound. Hence the decomposition of bodies is distinguished into proximate, and ultimate analy-

ses. But sulphate of soda, which when pure, is a dry opaque white powder; has a strong attraction for water, and combines with a certain portion of it, producing a transparent crystal of a peculiar form. This, speaking strictly, is a ternary compound; but as its properties are not otherwise affected, it is usually considered as the same body diluted by so much water.

There is a very wide difference in the changes produced in different bodies by chemical attraction. In some cases they are scarcely apparent: when alkohol is mixed with water, there is a slight condensation of the mass, and an evolution of a certain portion of caloric. In the solution of saline bodies in water, the aggregation of the solid is destroyed, caloric is absorbed, and perhaps there is a slight deviation from the medium specific gravity.

In other cases, the compound resulting from the combination of two bodies is altogether different from either of its elements. Oxygen is an inodorous inert body, when applied in an undecompounded state, to our organs, or to the bodies around us. Sulphur, also, is an insipid, inodorous body. The product of their combination is one of the most energetic and acrid of the acids. Sodium is a body which may be handled with perfect safety; and is energetic only in its attraction for oxygen, and chlorine; but pure soda is one of the most caustic, and destructive bodies that can be applied to animal or vegetable matter. When these two acrid bodies are combined, a mild saline, medicinal compound is produced, popularly called Glauber's Salt.

When a piece of iron, a metal, the properties of which are well known, is immersed in a certain quantity of diluted sulphuric acid, a chemical action commences; the atoms of the two bodies respectively attract each other; after a time, the atoms of both bodies have disappeared. The opacity, the metallic brilliancy, as well as the hard tough texture of the iron, are gone; the well-known caustic acrid

property, and sour taste of the acid has vanished also. Instead of these, a transparent soluble compound is produced, that has a sub-astringent taste, and readily crystallizes into beautiful diaphanous green crystals.

Sometimes the combination of two gasses produces a liquid; thus hydrogen and oxygen gasses form water. Sometimes two gasses combine into a solid. Thus the gas called ammonia unites with muriatic acid gas into the solid salt, called sal-ammoniac.

Liquids, by their combination, frequently produce solids. This is the case when strong solutions of carbonate of potash, and muriate of lime are mixed. Or they may produce gasses, as in the case of alkohol with nitric acid.

Solid bodies, on the contrary, may, by their combinations, produce a liquid, as is the case when nitrate of ammonia is mixed with Glauber salt; or when muriate of lime is mixed with ice. Or they may produce gasses; thus the various fulminating powders, and gunpowder, are, by their decomposition, converted for the most part into gasses. Also, when dry lime is mixed with carbonate of ammonia, a gas is produced.

Change of temperature almost universally attends chemical action. Caloric is almost always either evolved or absorbed. The mere addition of sulphuric acid to water, when in a certain proportion, raises the temperature from 60° to 260°. The mixture of muriate of lime and snow, may be made to produce a cold sufficient to render mercury solid.

The specific gravity of chemical compounds very rarely is the medium of the specific gravity of the elements.

The colour of bodies is subject to very great variation from chemical action; some colours are fugitive; and affected by very slight changes of composition; some are fixed, and can only be destroyed or changed by altering the compound. The colours of vegetable and animal bodies are generally less fixed than those of minerals. Certain vege-

table blues, reds, yellows, are used as tests of the presence of acid and alkali, from the instantaneous change these bodies produce in them.

The taste of bodies and the smell, are generally as much altered by chemical combination as their other properties. The most sapid bodies often produce insipid compounds; and sometimes insipid bodies produce compounds which are highly sapid. Nitrogen has neither taste nor smell; hydrogen is equally insipid and inodorous. Every one knows the highly acrid taste, and smell of ammonia, the body afforded by their combination. A certain acid, known by the name of the hypo-sulphurous, is to the taste, sour, bitter and astringent; soda is acrid and caustic; silver in its metallic state is tasteless; its solutions generally are very nauseous:—there is a compound of these three bodies, called hypo-sulphite of soda and silver, the taste of which is perfectly sweet, and so pungent is this sweetness that a few grains will sweeten a large quantity of water.

Sulphur, when pure, is devoid of smell; combined with a certain proportion of oxygen it produces a highly suffocating stinking gas; combined with a larger proportion it produces a highly acrid but inodorous acid. When sulphur is combined with hydrogen, a gas which when pure is inodorous, the compound has the nauseous smell of rotten eggs.

In short, the compounds resulting from chemical combinations produce properties sometimes resembling one or other of their elements; sometimes possessing what may be considered as intermediate properties; and frequently they are endowed with properties altogether different from those of either of the elements.

In the latter case it oftentimes happens that there is a strong analogy among the properties of compounds containing a certain element. Indeed most chemists appear to assume it as a general law. It is subject, however, to

numerous exceptions; frequently no such analogy can be traced; and sometimes there is a strong analogy between the properties of bodies, the compositions of which are altogether different.

Chemical attraction is not confined in its action to two elements merely. Many compounds are the production of three or more elements combining together. Not to mention the very numerous animal and vegetable compounds, or proximate principles, which are produced by vital actions, and which, although they retain their combinations after the actions that produced them have ceased to influence them, chemistry cannot imitate; there are many instances of such combinations.

There are many useful metallic alloys that consist of three or four metals chemically combined, and each contributing some necessary or useful quality. Glass is frequently a compound of silica, soda, lead, and manganese, and would lose its value by the absence of either of the ingredients.

In many cases where compound bodies become the chemical elements of other compounds, they appear to retain their state; and to act as if they were simple elements In other cases they appear to resolve into their primary elements, and to combine, forming triple or quadruple compounds.

In some cases chemical actions are much more complex than they at first appear to be. When concentrated sulphuric acid is added to iron, little or no action ensues: upon the addition of water a brisk action commences. Iron and sulphuric acid cannot act upon each other. It is necessary that the iron be combined with a certain proportion of oxygen. Upon the addition of water the united attractive forces decompose a part of it; the oxygen combines with the iron; while the hydrogen escapes in a gaseous state; and the oxide of iron thus produced combines with the acid,

. The force with which chemical attraction unites bodies, differs in different cases. When two bodies are chemically combined they can be separated only, generally speaking, by the addition of a third, which has a stronger attraction for one of the combining elements. Carbonate of soda is a salt that is well known: when sulphuric acid is added to this compound its superior attraction for soda produces a decomposition; sulphate of soda is produced, and carbonic acid set free. But when it is wished to obtain the soda pure, the addition of fresh burnt lime sets the soda free by its superior attraction for carbonic acid, with which it combines and produces chalk.

Water is a compound of hydrogen and oxygen. Potassium has a stronger attraction for oxygen than hydrogen has. Potassium therefore decomposes water, combines with the oxygen, and produces potassa, the hydrogen being set free.

Silver, or rather its oxide, is soluble in nitric acid, producing a transparent solution. Suppose we want to separate it: mercury having a stronger attraction for the oxygen and the acid than silver has, will on being added separate the silver in its metallic state, and take its place by combining with the oxygen and acid. Copper in a like manner will decompose the nitrate of mercury, setting the mercury free, and producing nitrate of copper. This salt may in its turn be decomposed, and the copper separated by means of iron. The nitrate of iron will be decomposed by the addition of zinc; and the nitrate of zinc may be decomposed by magnesia, and the nitrate of magnesia by potassa. Sometimes caloric appears to act as a third body: thus lime or magnesia are forced from water and carbonic acid by heat, leaving the base they are converted into gasses, seemingly by combining with caloric.

Attempts have been made to measure this difference, in the force or order of attraction, and numerous and exten-

sive tables have been formed by experiment and calculation, from which it was expected that the laws of chemical combinations, and the value of chemical forces, would be reduced to regular standards. Various anomalies arising out of variety in the temperature; difference in solubility, and quantity of the elements; or of the properties of the resulting compounds; the tendency in many cases to the production of compounds, consisting of two or three proportions of the same elements; or to the formation of compounds of three or four elements, or even the partial attraction of the menstruum in some cases; and other occasional sources of uncertainty; have rendered these tables less correct and valuable than might have been expected. Still, however, they are of great utility.

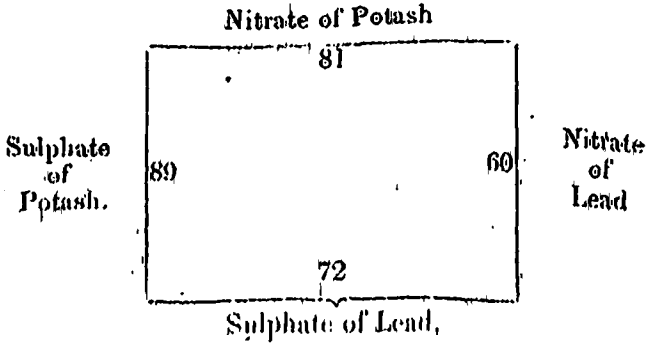
These tables, which were first begun by M. Geoffroy, and greatly extended by Borgman, by Mr. Kirwan and others, have more recently been arranged by Dr. Young, and improved, so far as relates to saline compounds, by the application of numbers to denote the respective attractive forces. But these numbers must be considered as arbitrary approximations merely. Thus suppose

Potassa to be attracted by Sulphuric acid with a force = 894
Nitric . . . . . = 812
Muriatic . . . . . = 804
Phosphoric . . . . . = 801
Fluoric . . . . . = 671

The fluate of potassa will be decomposed by phosphoric acid; the phosphate of potassa thus produced, by the addition of muriatic acid; and so on in succession. Tables denoting the order of attractions may thus be applied to oxygen, chlorine, or any other bodies.

Such cases as these, where a compound of two elements is decomposed by the addition of a third, are distinguished by the name of *single elective* attractions.

But suppose it is wished to decompose sulphate of potassa, by nitric acid; that is, to produce nitre; it is clear, on looking at the above table, that it cannot be done by the force of the nitric acid only, or by single elective attraction. But lead has a strong affinity for sulphuric acid, and the joint attraction of the lead for the sulphuric acid and of the nitric acid for the potash, may produce the wished-for decomposition. The nitric acid, and the lead have an attraction for each other; and on being put together, combine and form nitrate of lead. On mixing the nitrate of lead with the sulphate of potassa, four different attractive forces come into action; the attractions between the acids respectively and the lead, and those between the acids respectively and the potassa. The attractions between the elements of the sulphate of potassa, and those between the elements of the nitrate of lead, tend to preserve their combinations unchanged; and have, therefore, been called the quiescent attractions. The opposite attractions that now come into action, and tend to destroy the previous combinations, and to produce new ones; have been called the divellent attractions. These being the strongest, the sulphate of potassa, and the nitrate of lead, are in consequence both decomposed; while nitrate of potassa, or common nitre, and sulphate of lead are produced. It may be explained again by means of a diagram.



Supposing these numbers correct approximations to the real forces, it is seen that the quiescent forces amount to 89+60=149, and the divellent to 81+72=153. This case is an instance of *double elective* attraction. In practice, these cases occur much more generally than was formerly apprehended. They are very frequently and advantageously used in the chemists laboratory, and in various manufactories.

In all cases where an interchange of elements is produced in neutral saline compounds, in combinations with oxygen, with chlorine, and in many other cases, by virtue of double attraction; there is no excess nor deficiency produced of any one base. All the different elements concerned, although they vary from each other in their combining proportions, carry their corresponding proportions through all their changes. When nitrate of oxide of silver, for instance, is decomposed by mercury, the quantity of mercury that enters into combination, is precisely that quantity which absorbs all the oxygen of the oxide of silver; and the quantity of oxide of mercury thus produced, is precisely that quantity which is requisite to combine with the whole of the acid. A certain quantity of nitrate of mercury is produced, and the whole of the silver is restored to its metallic state. In the same way, a certain quantity of alkali is required to neutralize a given portion of any acid; a certain quantity of another alkali or of an earth, is necessary for the same purpose. Suppose that six parts of potash saturate a certain quantity of sulphuric acid, and that four parts of soda have the same saturating power; then, in neutralizing all the other acids, the respective quantities of potash and soda required, will be in the proportion of 6 to 4.

In the neutralizing and combining powers of acids, the same relations prevail. Consequently, in all cases of compound attraction among bodies equally neutralized, the elements of the new compounds must be in the exact pro-

portion required to produce the new compounds: there can be no superabundance of either element.

In all cases of complex chemical action, where the agents and products are definite compounds, this balance or equality of elements is found to prevail.

The observing of these phenomena in various instances, led first Mr. Higgins, and subsequently Mr. Dalton, and other chemists, to the opinion that bodies combine in certain definite proportions only. This doctrine is variously modified, according to the preconceptions of different chemical philosophers. It may be explained by supposing the different chemical elements, whether primary or secondary, to consist of a collection of atoms, using the term atom in the sense already defined.

When two elements of different properties, having a strong attraction for each other, are mixed in due proportions, they combine atom to atom, and produce a compound having its own peculiar properties; each atom of which is made up of an atom, or a certain number of atoms of the respective elements. Some bodies are capable of combining in one proportion only; the proportion is always definite, and so are the properties of the compound produced. When, as is often the case, the same elements are capable of producing more than one compound, it is effected by the combination of an atom of one element, with one, two, or more atoms of the other. In some cases, two atoms of one element combine with three, four, or more of the other, to form a compound atom. Sulphur and oxygen are known to combine in four different proportions. Supposing the proportion of sulphur to be unity; the proportions of oxygen are multiplies or submultiplies of each other. Thus,

1 proportion or atom of Sulphur + 1 Oxygen = Hyposulphurous Acid
. . . . . + 2 . . = Sulphurous Acid
. . . . . + 5 . . = Hyposulphuric Acid
. . . . . + 3 . . = Sulphuric Acid

Thus again, sulphuric acid combines with potassa in two proportions.

1 atom Acid + 1 Potassa = Neutral Sulphate of Potassa
2 . Acid + 1 Potassa = Acid or Bisulphate of Potassa

Carbon combines with oxygen in two proportions.

1 atom Carbon + 1 Oxygen = Carbonic Oxide
1 . . . . + 2 . . = Carbonic Acid

Carbonic acid also, combines with potassa and soda in two proportions.

1 atom of Carbonic Acid + 1 {Soda, or Potassa} produces Carbonate {Soda or Potassa}
2 atoms of . . . . + 1 {Soda or Potassa} produce Bicarbonate {Soda or Potassa}

In the same manner, there are two combinations of iron and oxygen. One consists of 28 iron to 8 oxygen, the other of 28 iron to 12 oxygen. There are two compounds also of mercury and oxygen. The first oxide consists of 200 mercury and 8 oxygen, the other, of the same weight of mercury and 16 oxygen.

It was discovered by Mr. Higgins, and further exemplified by M. Guy-Lussac, that bodies in the gaseous state, however they may vary in specific gravity, combine in proportions that are as their volumes, or as multiples of their volumes. There is a relation, then, in the size of the atoms of different gasses; they must be of the same size, or of sizes increasing as the ratio of the multiples 1.2.3.4, &c. Thus, two volumes of hydrogen in weight 2, combine with one of oxygen, in weight 16, and produce water. The vapour of water at 212°, consists of these three volumes of gas condensed into two volumes. Thus also, one volume of hydrogen, in weight 1, combines with an equal volume of chlorine, in weight 36, and produces two volumes of muriatic acid gas. Again, one volume of oxygen, and two volumes of nitrogen combine, and produce two volumes of a gas called the first, or protoxide of nitrogen. One volume of oxygen and one of nitrogen, produce two volumes of the gas called deutexide of nitrogen. One volume and a half

of oxygen combines with one volume of nitrogen, and produces one volume of nitrous acid gas, and two volumes and a half of oxygen combine with one volume of nitrogen, producing one volume of nitric acid gas. In all these cases, as we see, and in numerous other experiments, it has been shewn that gasses combine in relative volumes, and, also, that the resulting compound, when condensed, is condensed regularly in the ratio of their volumes.

The generality of these laws, extending, as it appears to do, to all definite compounds, has produced the doctrine of chemical equivalents—one of the most valuable applications that has been made to chemistry. In the explanation of this law, the term, prime equivalents, corpuscles, proportionals, particles or atoms, are hypothetically applied with the same meaning. They mean the supposed smallest combining proportion of any given body, and should mean no more: the shortest word appears the most convenient.

Now, the absolute weight of an atom of any body cannot be known, nor has any estimate been attempted; but an immense number of experiments have enabled chemists to attain some approximations to the relative proportional weights of the atoms of most bodies; and the labours of many eminent chemists are, at this time, employed in extending and perfecting this part of chemistry.

Since our knowledge of the atomic proportions of different bodies, is merely relative; it is necessary to adopt the atom, or smallest combining proportion, of some one body, as a standard.

It were to be wished, that chemical philosophers had agreed in the adoption of one body only, as a standard; and employed a simple order of numbers, in the explanation of chemical equivalents; the study of the subject would have been more simple, and some confusion have been prevented.

Since it is probable that, could all bodies be combined in

their gaseous state, their combining proportions would be as their volumes. It is desirable, also, that chemists would have a reference to the specific gravity of the respective bodies in their gaseous state, in assigning the atom, or smallest combining proportions.

Three orders of numbers are now employed.

Hydrogen is the body whose combining proportion is the smallest of any: it combines in equal volumes with chlorine, with nitrogen, with gaseous carbon, and some other bodies: its specific gravity is to that of oxygen as 1 to 16: it produces water, by combining with oxygen, in the proportion of two volumes to one of oxygen. Sir H. Davy, therefore, and some other chemists, adopted hydrogen as a standard, calling it 1, and oxygen 16. Thus, supposing the combining atoms to be of the same magnitude, their weights are as 1 to 16, and two atoms of hydrogen combine with one of oxygen in the production of water.

It is at least as probable that the atoms, or combining proportions of gasses, are all of one size, as it is that they are exactly two or three times the size of each other, since they must possess one or other of these proportions; and the simplicity of the former estimation is a recommendation.

When one volume of hydrogen is used as a standard, the weight of the combining proportions, or supposed atoms, of all other gasses, is, as the specific gravity of their volumes; in other bodies the proportionate weights of the atoms are simple multiples of hydrogen.

Mr. Dalton, and some other chemists after him, amongst whom are Dr. Henry, Mr. Brande, and Mr. Children, have thought, that since two volumes of hydrogen are necessary to produce a neutral compound with one volume of oxygen; while an equal volume of each are combined with great difficulty, and produce a compound which is neither stable nor neutral; the atom of hydrogen must be two volumes, or

double the magnitude the atom of oxygen is of, and that its weight is, consequently, ½ only of the weight of the atom of oxygen; and, in consequence, notwithstanding the cases above referred to, in which hydrogen combines with some other gasses in equal volumes, they, in adopting hydrogen as a standard, have doubled the size of its supposed atom. Thus, according to their standard arrangement, an atom, or combining proportion of hydrogen is 1, an atom of oxygen is 8.

Dr. Wollaston, in the formation of his scale of equivalents, adopts oxygen as the standard, calling its lowest combining proportion 1.000; that of hydrogen as two volumes, or 0.125; in this he has been followed by Dr. Thompson, Dr. Ure, and some other chemists.

In this elementary outline, it is thought best to follow the path that appears to be most generally adopted in this country. This is Mr Dalton's.

Dr. Wollaston's scale is formed upon the principle of Gunter's and Beavan's scales; it is a valuable instrument to both the experimental and practical chemist.

The proportions in which bodies combine, depend, therefore, upon the relative weight of their respective atoms, or combining equivalents. Of the greater number of bodies, approximations to this relative weight of their atoms, have been obtained, after the numerous successive experiments and calculations of different chemists.

Thus, hydrogen being taken as a standard, and oxygen reckoned as 8;

The atom, or smallest combining proportion of			
Chlorine is . . .	36	Carbon	6
Iodine	125	Sulphur	16
Nitrogen	14	Phosphorus . . .	12
Potassium . . .	40	Calcium	20
Sodium	24	Magnesum . . .	12
Barium	70		

Thus also it has been found, that

		atom. weight.			atoms. weight.	
Sulphuric acid consists of Sulphur . . .		1 or 16	+	Oxygen	3 or 24	= 40
Nitric Acid .	Nitrogen	1 or 14	+	. .	5 or 40	= 54
Muriatic Acid	Chlorine	1 or 36	+	Hydrogen	1 or 1	= 37
Carbonic Acid	Carbon	1 or 6	+	Oxygen	2 or 16	= 22
PhosphoricAc.	Phosphorus	1 or 12	+	. .	2 or 16	= 28

The following alkaline bodies also are found to consist,

	atom. weight.			atoms. weight.	
Potassa of Potassium	1 or 40	+	Oxygen	1 or 8	= 48
Soda of Sodium . .	1 or 24	+	. . .	1 or 8	= 32
Ammonia of Nitrogen	1 or 14	+	Hydrogen	3 or 3	= 17
Bayrta of Barium .	1 or 70	+	Oxygen	1 or 8	= 78
Lime of Calcium .	1 or 20	+	. . .	1 or 8	= 28
Magnesia of Magnesium	1 or 12	+	. . .	1 or 8	= 20

In the combinations of these bodies, to produce secondary neutral compounds, the combining proportions are as their atomic weights.

To produce a neutral sulphate, for instance, the chemist takes as much common sulphuric acid as contains 40 parts of pure acid, and adds to it 48 parts of pure potassa—32 parts of soda, or 17 of ammonia, and so on; or of some decomposable compound containing it, a carbonate for instance; when the sulphuric acid, by its superior attractive force, combines with the base the carbonic acid escaping.

Thus we see, that in all the above-named bodies, the weight assigned to their atoms is equivalent to their combining proportions.

Metals, it has been observed, all combine with oxygen, but in different proportions. When the oxide consists of the metal and oxygen, combined atom to atom, the difference of proportion depends upon the difference there is in

the weight of the respective atoms of the metals, and not, as was once supposed, upon the force of attraction. In the combination of metallic oxides with acids, the neutral and most perfect compounds appear to consist, in most cases, of one atom of each. In the production of the metallic salts of any given class, of sulphates for instance, the proportion of oxygen combined with the metal, to form the oxide, bears an uniform relation to that in the acid. Thus oxide of silver consists of an atom of silver and an atom of oxygen; sulphuric acid consists of sulphur 1 + oxygen 3. When sulphate of silver is decomposed by mercury, an atom of mercury combines with each atom of the oxygen given up by the silver; and the oxide of mercury then formed, is exactly in that proportion required to combine with all the atoms of sulphuric acid, which were combined with the oxide of silver: hence the silver appears in its metallic state. Should the sulphate of mercury be decomposed by copper, the sulphate of copper by lead or zinc, the same changes will take place, and, consequently, the same proportions be observed between the oxygen in the acid, and that in the base.

If this experiment be made with nitric acid, instead of sulphuric, then, since nitric acid is a compound of 1 nitrogen and 5 oxygen, the proportion of oxygen in the oxide will be to that in the acid as 1 to 5, and that proportion will continue through all the combinations; while the metals are successively separated in the metallic state.

Bodies then, in general, are capable of combining in certain definite proportions only, and these proportions are multiples, or submultiples of each other.

Many of the metals, as far as is known, combine with oxygen in one proportion only; many appear to combine in two proportions only, some in three only, and some in more. There is, however, in some of these instances, a

difference of opinion among chemists. Thus, some have supposed iron to be capable of combining with oxygen, in two proportions only; others have attributed three to it; and others even more. Manganese is generally supposed to combine with oxygen in three definite proportions, but some chemists have thought it capable of combining in four or five. In combinations of the metals with sulphur, with chlorine, and with each other, similar differences of opinion occasionally prevail.

These differences arise out of various anomalies and complicated appearances, produced by various causes; frequently by the complicated properties, and attracting forces of the different agents employed in an experiment; sometimes a supposed intermediate compound is merely an intimate mixture of two others. Temperature frequently affects the proportions in which bodies combine. In some cases, the presence or absence of water, or even a difference in the proportion of it, produces anomalous changes, by affecting the appearance, the colour, and sometimes, by its own attractive force, affecting the proportions in which bodies combine; and frequently chemists are biassed by their preconceived theories.

Some bodies, as we have before said, combine in all proportions, the attraction between them is slight, and very little change is produced in their respective properties. It is not easy to consider them other than mere mechanical mixtures. The mixture of alkohol and water, sulphuric acid and water, are of this kind. Gradually increasing attractive forces may be traced through nature until we arrive at the most powerful. As we advance we find chemical combinations become definite, both in the proportions of their elements, and in the properties of the compound produced. But even here, at times, the opposing attractions are so balanced, as to give rise to anomalies. Saline bodies are va-

riously soluble in water; some not at all; some are soluble in other menstrua, in which others are not. Some are soluble to a certain quantity only, at which point the water or menstruum is said to be saturated. Others appear to be soluble to any extent: but even in these cases of apparently slight chemical attraction, on attempting a complete separation of the watery menstruum, the last portions of it are retained with great force. Muriate of lime, and many other soluble saline bodies, retain a portion of water at a red heat.

It was observed by Berthollet, that, in various cases, a body produced by the union of two elements that have a strong attraction for one another, may be partially decomposed by the addition of a third element, the attraction of which is weaker: thus, when potassa is boiled with sulphate of baryta, it decomposes a portion of it.

Lime, in the same manner, decomposes a portion of a solution of sulphate of potassa.

Potassa, or nitric acid, act in the same manner upon oxalate of lime.

Potassa, boiled with chalk, will attract a portion of its carbonic acid; and soda will decompose part of a solution of sulphate of potassa.

There are other difficulties and anomalies occasionally occurring.

Some of these apparent irregularities are readily explained; but some of them are not explicable in the present state of chemical knowledge, although they may probably be cleared away as the science advances.

Various considerations and precautions are therefore necessary in the production of chemical combination, where accuracy is necessary, and the precautions require to be varied, according to the properties of the bodies to be acted upon.

Temperature is one of the most general and important agents in chemical action. Not only does it effect, in many cases, the disintegration of bodies, and bring their atoms within the sphere of their respective attractions; as in the formation of gasses, or the fusion of metals; and, in other cases, separate bodies from the sphere of attraction, by converting one of them only into gas or vapour, as in common distillations; or in the decomposition of carbonate of magnesia, or lime, &c. by exposing them to a red heat; but it frequently changes the order of attractions so much, that in cases where several forces are brought into action, different compounds are frequently produced according to the temperature which has been used.

At the atmospheric temperature, muriate of lime and carbonate of ammonia decompose each other; carbonate of lime and muriate of ammonia being produced. Upon the application of heat, the order of their attraction is reversed, and muriate of lime and carbonate of ammonia are reproduced. Indeed the purest carbonate of ammonia that is prepared for sale, is obtained by the decomposition of muriate of ammonia by carbonate of lime at high temperatures.

Metallic oxides are generally decomposed by means of charcoal. However completely they may be mixed together at the temperature of the air, no action takes place. But on increasing the heat to a temperature, varying according to the properties of the metal, the carbon attracts the oxygen, and is converted by it into an oxide, or an acid, the metal assuming its metallic state.

In consequence of caloric altering the degrees and order of attraction in some cases, it is frequently necessary to use precautions to keep the combining mixture at a low temperature, by surrounding it with ice, or frigorific mixtures. Thus, in the combination of mercury with nitric acid, a protonitrate is produced at a low temperature; a nitrate or subni-

trate of the peroxide, if the temperature be permitted to rise. The influence of temperature is so general, and so important, and the management of it requires so much address, in some cases, that it constitutes one of the principal difficulties to be overcome in the practice of chemistry.

In cases of simple solution, as of sugar, or saline bodies in water, an elevation of temperature increases the rapidity of the solution, frequently in more than a ten-fold degree. Many saline bodies are much more soluble in water at 212°, than in cold water; but some, common salt for instance, is equally soluble in water at all temperatures; and some few bodies, among which is lime, are more soluble in cold water than in hot.

It is necessary that bodies exposed to each other's action should be in a state of disintegration. A lump of hard sugar is some time in dissolving. A lump of carbonate of ammonia dissolves slowly in vinegar; or a lump of marble in dilute muriatic acid. If these bodies are reduced to powder, the solution is very rapid. A lump of antimony put into chlorine gas is scarcely acted upon; if introduced in fine powder, it inflames and burns rapidly. Solids, when of difficult solubility, require to be reduced to an impalpable powder. Alumine, for instance, when newly precipitated, is readily soluble in sulphuric acid, or in potassa; but a ruby, or a sapphire, solid crystals of the same body, is insoluble in both. In the decomposition of minerals, tedious circuitous processes are sometimes necessary, to produce a sufficient degree of disintegration.

When two solid bodies, that have an attraction for each other, are mixed, their atoms appear to come in contact at certain points only. There they will combine. If the product be a solid, no further combination can ensue. If it be a fluid, either it gradually escapes and the remaining atoms successively fall into contact, and combine; or it serves as

a menstruum, or medium of communication between the remaining atoms. Therefore, although it cannot be said that fluidity is necessary for chemical combination; yet, unless one of the combining bodies, or of the resulting compound be a fluid, the chemical combination will be imperfect and limited. When a small quantity of dry nitrate of copper is spread over tin-foil, and the foil rolled up, no action ensues; but when a little water is sprinkled over it, inflammation and flame are produced.

When dry muriate of soda and dry ice are mixed at the temperature 28° or 30°, the atoms that lie in contact combine and produce a fluid, which serves as a medium for bringing the remaining atoms into contact. If the cold that is produced during the solution should be so great as to freeze, or solidify the mixture; which will take place on the temperature falling to —4°, all further combination ceases, as will be known by the temperature ceasing to fall further.

In the preparation of chemical compounds, it is necessary, in many cases, that the elements be added in their proper equivalent proportions. Lime dissolves in water, producing a transparent solution; a certain quantity of a solution of carbonic acid precipitates the lime in the state of chalk, an insoluble compound; if the quantity be increased, the lime is not precipitated, or if it has been, it is re-dissolved; for super-carbonate of lime is soluble in water.

It is oftentimes of consequence which of the elements of a compound shall be added to, or poured upon the other. Thus tartaric acid is very soluble in water, so is potassa: if a solution of tartaric acid be added to a solution of potassa, the gradual addition may be continued without interruption until the potassa is neutralized. But if the solution of potassa be poured into the tartaric acid, a comparatively insoluble precipitate of bitartrate of potassa falls down, which requires a large quantity of water for its so-

lution. So, on the contrary, when it is intended to produce bisulphate of potassa, if the sulphuric acid, which is soluble in water in all proportions, be added to the potash, a neutral sulphate, which is of difficult solubility, will fall down, and delay the process; if the order of the mixture be reversed, a soluble bisulphate of potassa is produced, and may be crystallized with little trouble. Even in the mere mixture of sulphuric acid and water, an attention to this apparently trifling circumstance is requisite. When water is poured upon sulphuric acid, the evolution of heat is so sudden, that a portion is instantaneously converted into gas, with a sort of explosion, which frequently throws a part of the water and acid into the face of the operator.

When one or both of the combining elements are in the state of gasses, a certain degree of pressure is sometimes requisite in order to preserve them in contact. The pressure that may be necessary will, of course, differ in different cases. In many combinations no pressure is required; in many others the usual pressure of the atmosphere is sufficient; but in some cases a much greater is requisite. Thus, muriatic acid and ammonia, in however rare a state, are condensed into a solid the instant they meet. Fluoboric acid attracts the vapour of water from almost every other body, and they are instantaneously condensed. Thus again, marble, a compound of lime and carbonic acid, is decomposed under atmospheric pressure, at a red heat, the carbonic acid escaping into the atmosphere, in the state of a gas. But when marble is exposed to a much higher temperature, under a sufficiently powerful pressure, it may be fused without decomposing it.

The sudden compression of two mixed gasses, which have an attraction for each other, will often produce their combination: it brings their atoms more closely together, and produces an elevation of temperature.

It has already been seen that electricity is the most powerful of the chemical agents. It has been seen how striking its effects are when applied artificially. Its agency through nature is general, though it is often obscure. It acts a part in every case of chemical combination, and frequently determines or changes the order and effects of attractions. The investigations of the laws that govern this influence, is a part of the science of chemistry, which is as yet in its infancy; but the road is opened, and several branches of it are extending at this moment.

What are called the chemical properties of a body are rather the result of the joint action of two or more bodies upon each other; for chemical attraction must be considered as a mutual or conjoined force, resulting from the properties of two or more bodies.

Although bodies differ much from each other, there are various resemblances, and strong analogies among numbers of them in their sensible properties. There are very strong analogies also among many of them in their various chemical properties. But these analogies, which, in some respects, are extensive with some degree of regularity, are so irregular in others, and cross each other in such various directions, that it is difficult to mark out such characteristic general distinctions as are sufficiently clear, comprehensive, and simple, to form the basis of a classification of them, for the convenience of description and recollection. The most active and familiar chemical agents, the acids, the alkalis, the alkaline, and earthy oxides, bodies that contribute most extensively to the mass of our globe, are all compound bodies. They are, in their chemical properties, very distinct orders of bodies; and the individuals of each order strongly analogous to each other; and the analogies are so strong in some cases, that it appears improper to separate them. But on comparing them with their elements, or the elements with each other, these

analogies cease, and new analogies offer themselves to our notice, and cross each other in different directions, and to different extents. Elements differing widely from each other produce, in some cases, analogous compounds; in other cases, elements which are analogous, nay even the same elements, by varying their proportion, produce compounds the most opposite in chemical properties. Several bodies combined with oxygen, in one proportion, produce compounds that act the part of an acid, while in another proportion, and in another combination, compounds are afforded which act as an oxide or earthy base. Even the distinct and striking property of acid, and alkali, are varied in a regular gradation until their boundaries are lost in each other. From soluble alkalies to the most insoluble oxides, the gradation is regular. Upon a more accurate examination many of these oxides are found to be acting as acids in some of their combinations. Not long since a chemist would have been thought deranged in venturing to assert that silica, in some cases, acts and combines as an acid. Some of the oxides; oxide of titanium for instance, appear also to combine as acids; and there is little doubt but that other metallic oxides, as well as other compounds, will be found to possess similar properties. The result is, that although acids, saline bodies, and their compounds, occupy a principal and extensive part of chemistry, and one that was considered as the best known, it would be no easy matter to produce such a list of acids as would satisfy the majority of chemists.

These bodies might, without difficulty, be arranged and treated of according to the analogy of their sensible properties; but the principal object of the chemist's attention is, not their sensible, but their chemical properties; and these frequently obey different analogies from the former.

If, on the other hand, they are treated of according to their chemical analogies—according to the primary and

most important compounds they produce, not only would the chemical arrangements of them be too violently dissevered from that of their natural history, but great confusion, and frequent repetition, would arise out of the very different properties produced by the different combinations into which the same body enters.

What can be more distinct in their properties than the acids. A general analogy in many of their most obvious properties runs through the whole of them. A general analogy also extends through the alkaline, earthy, and metallic oxides. These two classes of bodies are opposite in their properties, and antagonists to each other. But upon examining the combinations that produce them, it is found that both owe their distinctive properties, in many cases, to the same primary elements.

When the French chemists, some years since, undertook to reform the barbarous language of chemistry, and to introduce a new nomenclature; oxygen, the parent of acids, was the name given to a well-known elementary body; on account of its supposed universal agency in producing acids, by combining with different bases. It was known to them that the same body, by its combination with many of the metals at that time known, produced what are now called oxides, bodies that were antagonists to the acids, and possessed of various properties in common with the alkalies. But this anomaly was not regarded; more especially as it was found, that many of these oxides were converted into acids by being combined with an additional proportion of oxygen. As all the acids of which they knew the composition contained oxygen, they hastily concluded that all acidity was occasioned by it.

Subsequent discoveries have shewn that it is more completely the parent of bodies having alkaline properties than of acids; but that, although it is the most general parent of both, yet, in some cases, it is not the parent of either.

Chlorine, which as far as is at present known, is a simple chemical element, combines with bodies almost as generally as oxygen does, and with greater energy and force, producing compounds which bear a certain analogy, some of them a very close one, to the compounds of oxygen. It assists, without the help of oxygen, in the formation of some acids; and it combines with all the metals, producing a class of bodies named chlorides.

Hydrogen combines also with chlorine and with iodine, producing acids: the same with sulphur, and with some other bodies. There is an acid composed of carbon, nitrogen, and hydrogen and another in which sulphur is joined with these.

It may be thought, that still, since the acidifying and alkalizing properties are confined to a few bodies, some plan of arrangement might be founded upon them. But hydrogen and sulphur differ from chlorine and oxygen in too many other properties to be included, with utility, in the same division.

In speaking of caloric, it was seen that this agency is evolved in great abundance during certain chemical combinations, and that there is an extensive analogy among certain bodies, in relation to this evolving property: this analogy is very often, it may be said generally, used as a ground for arrangement. Oxygine, and chlorine, and iodine, in this point of view, have analogous properties; and almost all the other chemical elements are, in different degrees, antagonists to them. This analogy amongst a great number of bodies, as contrasted with oxygen, has long been observed, although not understood; and has procured to these bodies the name of combustible; from the supposition that they are the sources of light and caloric. So obscure however is this subject, that it is at least equally probable that these agencies are supplied wholly, or in part, from the oxygen or chlorine; and it is still more probable, that when caloric is produced in great abundance, the greatest part of it is not pre-

existent in either of the combining bodies; that it is, in some unknown manner, excited and collected by the energy of the chemical agencies that are in action. But it does not thence of necessity follow, that it consists merely in the vibrations or revolutions of elementary atoms on their axes.

We have ever, until lately, been accustomed to look at certain masses of matter as being absolutely impenetrable to each other. If a neutral salt, an acid, an alkali, and a portion of water, were shut up in a sound vessel, we have been accustomed to consider them as being undoubtedly confinable and safe; and that they could not escape, nor be transferred, without our perceiving the outlet. But it is now well-known that, under the influence of electricity, these bodies can assume a protean state; can escape from under our eyes, and contrary to their *supposed* well-known properties; appear issuing at a distant place, from what was supposed to be a solid impenetrable body. Is it wonderful then, that caloric should still more readily elude our senses and judgment, in its passage to the point of its excitement?

We have seen that the same mass of matter may be made to assume the state of a solid, a liquid, or a gas; we have seen further, that by means of electrical agency it may be made to assume a state in which it is capable of being apparently conducted through bodies supposed to be impermeable to it. Some chemists are inclined to extend these protean properties of matter; and hence appears to arise the term, radient *matter*. That light and heat radiate is well known. In the state of radiation only, is light an object of perception; its intimate connexion with caloric, and their apparent resemblance in some of their affections, leads to the probability, that they may be modifications of the same agency: but, that any one of those bodies which all the world have consented to call matter, is dispersed by radiation, or is converted by radiation, into light and caloric,

has not been proved. How caloric, while its materiality is doubted or denied, in contiguous or chemical communication, shall become matter when radiating, is not explained neither.

In the arrangment of bodies according to their electrical affections, difficulties occur. The bodies that are decomposed by the electrical agency, consist of elements the atoms of which become oppositely electrified in relation to each other; and that are in consequence attracted to the different poles. Hence the elements of bodies become distinguished as electro-negative, and electro-positive. But the properties are relative merely. There is only one element that, speaking strictly, is electro-negative; all others are electro-positive in relation to it. On the other hand, there is only one universally electro-positive body; and to it all the other elements are electro-negative. But when they are arranged according to their electrical tendencies there will be a gradation, and every element will be electro-negative to those below it, and electo-positive to those above it.

This gradation, first pointed out by Sir H. Davy, has since been partially adopted by some chemical writers. It coincides, and appears to be intimately connected with some of the most striking chemical affections, and so far is wholly unobjectionable, if the order were strictly traced. But chemistry has succeeded in reducing a great number of its principal agents into elements which have the sensible properties of metals, and are so strongly connected by their physical analogies as to render it almost necessary, at present, to class them under one head. At the same time, the great number of them, the analogous chemical properties that prevail among the compounds of some of them, and the diversity that prevails among others, renders sub-division a very convenient assistant to the memory, if not a necessary one. It appears too, that a subdivision founded

upon the analogy of the primary compounds is more convenient, than one founded upon electrical relations, which indeed are known to a certain extent only.

There are some bodies that have not been satisfactorily reduced to their simple chemical elements, apparently on account of their very powerful chemical attractions; while scarcely a doubt is left of their compound nature. In some cases, various transient phenomena have shewn a momentary decomposition, which is instantly obscured by a recombination, through the agency of one or other of the surrounding bodies. In some cases, chemists are induced to consider these as compounds from their very strong resemblance and chemical analogy to bodies that have been decomposed into more simple elements. These bodies may be placed by themselves as elements, or they may be placed provisionally among those bodies to which they have the closest analogy. Under this complicated train of considerations, it is scarcely to be expected that chemical writers should agree in relation to the minor arrangements of the objects of chemical science. Any arrangement that is made in the present state of chemical knowledge, can be provisional only; it is not practicable to make a perfect division where nature appears not to possess one, and where many of the properties of bodies are unknown or assumed. In the present case, that arrangement is adopted which, although it is not strictly logical, appears the most simple, and best adapted to assist the memory, and to convey a general knowledge of the bodies treated of.

When the number of chemical elements, and all the varieties of compound bodies that each of them may be capable of producing with any one other element, is considered; when it is considered further, that a great number of compounds consist of three, four, or more elements in various proportions, it will be seen what an immense number of facts a tolerably complete system of chemistry must contain.

In this place, our limits will confine us to a general outline only; many things of minor importance must be wholly passed over: but such bodies, as by their abundance, their utility to man, the singularity or importance of their chemical properties, or their aptitude for explaining certain chemical laws, that may come under consideration, will be more fully dwelt on and explained, as the occasions occur. The same necessity for brevity obliges us to pass silently over controversial points, and prevents our tracing to its various sources, the information detailed. The unlearned reader, should his taste and inclination lead him to wish for further information, will of course, pass on to more extended treatises on the subject, or on particular branches of it.

We shall speak of the material chemical elements, therefore, under the following heads.

1. The electro-negative simple acidifiable elements, and their combinations with each other.

2. The electro-positive simple acidifiable elements, and the compounds resulting from their combinations with the preceding elements, and with each other.

3. Metallic elements, and the compounds resulting from their combinations with the preceding elements, and with each other. As these bodies are numerous and diversified in their properties, for the convenience of the recollection, they shall be subdivided into

1. Metals, that combined with oxygen, produce alkalies.

2. Metals, that combined with oxygen, produce alkaline earths.

3. Metals, that combined with oxygen, produce simple earths.

4. The acidifiable metals.

5. The metals which produce oxides undecomposable by caloric alone.

6. The metals whose oxides are decomposable by caloric alone.

PART 2. *Of the Electro-negative Acidifiable Chemical Elements, and their Compounds with each other.*

ARTICLE 1. The three elements included in this chapter are distinguished from others, not so much by the exclusive possession of distinctive analogous properties, as by the peculiar degree in which they possess them. They are electro-negative in relation to all other elements: but iodine is electro-positive in relation to chlorine, and so probably is oxygen.

Their chemical attractions for each other are very feeble and the compounds produced between them are, for the most part, acid. They have, generally speaking, a strong attraction for the greater number of simple acidifiable and metallic elements; and one of them contributes to the production of the greater number of acids. In their combinations with other elements, peculiar compounds are generally produced; and caloric liberated, sometimes in large quantities accompanied with light and all the phenomena of combustion.

Oxygen exerts in nature the most general and extensive agency, and is necessary to animal and vegetable life; but its attractive forces are generally weaker when acting singly, than those of chlorine. Iodine occurs sparingly, it closely resembles chlorine in many of its properties, and in the compounds it produces. Both are destructive of animal and vegetable life.

ARTICLE 2. OF OXYGEN.

Oxygen is one of the most abundant bodies in nature, and is the most general in its existence and agencies. It forms an essential part of the atmosphere. It contributes

in great proportion to the formation of water; and, in combination with chlorine and other elements to the mass of saline matter that characterizes the water of the ocean, and preserves its freshness.

With two or three exceptions, it is occasionally met with and naturally combined with every known element; and its combinations with the different elements appear to make a great part of the matter of the globe. It is an element in almost all animal and vegetable bodies, and is absolutely necessary for the support of animal and vegetable life.

And yet it was unknown as a distinct body until discovered by the late Dr. Priestley in 1774, when he produced it, and ascertained a few of its properties.

It is, as may be expected, obtainable from a great number of compound bodies. When nitre, a body called black oxide of manganese, oxide of lead, or red oxide of mercury, or the compound called chlorate of potassa, are exposed to a red heat in a retort; this gas is given out, and may be collected in a vessel inverted over water or mercury. The two latter bodies give it out in a very pure state.

It is a permanently elastic fluid uncondensable by any mechanical means, transparent, colourless, inodorous and insipid; but it appears to stimulate highly irritable living surfaces.

It is attracted from all its chemical combinations, that with chlorine perhaps excepted, to the electro-positive pole.

Its specific gravity, in comparison to hydrogen, the lightest of ponderous bodies, is as 16 to 1; to atmospheric air it is as 1.1111 to 1, and 100 cubic inches weigh 33.888 grains nearly, at 60°.

The weight of its atom, or smallest combining proportion according to the estimation adopted, is half its specific gravity as compared with hydrogen; or 8.

Its agency in chemistry is, of course, very extensive; and is generally more or less active wherever atmospheric air or

water may be present. It appears to combine with all bodies in one or more different, but definite proportions. When it combines with the same body in different proportions, these proportions are multiples or submultiples of its equivalent or prime number or atom, and each compound has its peculiar or distinctive properties. The products of its combinations with different bases are, the greater number of the acids; three of the alkalies, the alkaline earths, the earths, the metallic, and other oxides.

Indeed, all its chemical combinations that have not distinct acid properties, are called oxides. When it combines with the same base in several proportions; those combinations containing the smaller proportions of it generally prove oxides; and those containing the larger proportions frequently have the properties of acids. Where two acids are produced; that containing the lesser proportion of oxygen, is generally distinguished by the termination —*ous*, and is generally the weaker acid; the acid containing the larger proportion is distinguished by the termination —*ic*. The compounds of the former acids with different bases are distinguished by the termination —*ite*, those of the latter by the termination —*ate*.

When, as is sometimes the case, more than two acids are produced by the same element, they are generally distinguished by the addition of a diminutive to the name previously assigned that acid which next exceeds it in the proportion of oxygen. Thus, hypo-sulphurous acid, sulphurous acid, hypo-sulphuric acid, and sulphuric acid, contain progressively increasing proportions of oxygen.

Strictly speaking, the term base is equally applicable to all the elements of a compound. Convenience, however, has induced chemists to restrict the term, in treating of saline compounds to the oxide, earth, or alkali, and to speak of a saline body as consisting of an acid and a base.

The constant respiration of a certain portion of this gas

is absolutely necessary for the support of animal life, nor can vegetable life continue long without it. Atmospheric, and other respirable airs, are respirable only in consequence of the uncombined or unneutralized oxygen they contain. Every animal has lungs or some analogous organ. Fishes have gills upon which the oxygen in the water they inhabit exerts its agency. Animals of a lower order have spiraculæ, upon the surface of which the blood is exposed to the influence of oxygen. In all these cases, both the blood, and the oxygen of the air, undergo a known chemical change; but it is unknown how these changes are connected with life.

Atmospheric air, which is oxygen diluted, is found to be better adapted to the support of animal life than pure oxygen; but it does not appear that the nitrogen performs any office except that of diluting the oxygen. It appears also that a part of the respired oxygen combines with a small portion of carbon that is emitted from the lungs: but what peculiar function it fulfils, which is so essential to life that it cannot, in numerous animals, be dispensed with for twenty minutes at a time, is wholly unknown.

Combustion, when produced with pure oxygen, is increased in proportion to the increased power of combination between the combustible, and the oxygen. The consequence is, that it is increased in vehemence, and rapidity; sometimes five-fold or more; and many bodies that are not readily, or not at all, combustible, when ignited and exposed in atmospheric air, when exposed to oxygen gas, burn readily. A small steel file, for instance, if the point of it be set on fire in oxygen gas; as is readily done by attaching to it a bit of burning phosphorus, will progressively evolve sufficient caloric to support its own combustion, and will wholly burn away, throwing off the protoxide thus produced, in sparks, which dazzle the eyes with their brilliancy.

The very general and necessary agency of atmospheric air in the production of caloric, in our common fires, has been already pointed out, and its properties in this respect depend wholly upon the oxygen contained in it. The nitrogen appears to have no other effect than that diluting the oxygen, and thereby lessening the force and rapidity of the action.

Oxygen may be diluted with nitrogen, or with other gasses, so far as to lessen or even to prevent combustion: the same effect may be produced by rarefaction.

Different bodies are capable of burning at different temperatures, according to their attractions for oxygen. Those which are capable of burning at a low temperature, will burn in air or oxygen more highly diluted, or more rarefied. Those bodies, again, that evolve most caloric during combustion, are capable, other circumstances being equal, of burning in more diluted, or more rarefied air. The combustion of a body continues so long as the caloric evolved produces a temperature sufficient to support the chemical action that is going on, whatever may be the rarefied state of the air. The flame of a very small jet of hydrogen, when received, in Davy's experiments on the safety-lamp, into atmospheric air, in the receiver of an air-pump, enlarges as the receiver is slowly exhausted, and is at its maximum when the air has lost $\frac{4}{5}$ of its density. As the rarefaction increases, the flame diminishes below: burning above until the density is reduced to $\frac{1}{5}$. When the jet was rather larger, the flame continued until it was reduced to $\frac{1}{10}$; and when a spiral coil of platinum wire is introduced into this flame, and kept ignited by it, the dissipation of caloric being then in part retarded by the platinum, the combustion goes on until the density of the air is reduced to $\frac{1}{15}$. He found, also, that olefiant gas burnt, under the above circumstances, with a platinum coil, until the density of the air was reduced to $\frac{1}{15}$ nearly. Carburetted hydrogen ceased

to burn, under the same circumstances, when the density of the air was reduced to $\frac{1}{4}$. Carbonic oxide, under the same circumstances, ceased to burn when the density was reduced to $\frac{1}{5}$. A small flame from alkohol, and from a wax taper, when the platinum was not used, ceased to burn before the density of the air was reduced to $\frac{1}{6}$, with the platinum the flame continued until it was reduced to $\frac{1}{8}$. Sulphuretted hydrogen burnt in air without platinum, until its density was reduced to $\frac{1}{10}$ nearly. Phosphorus burns in air until its density is reduced to $\frac{1}{60}$, or more.

Combustion will also cease, if, instead of diluting and rarefying the air, the burning body be surrounded by substances that carry away the caloric faster than it is evolved; for, as soon as the temperature is, by this means, reduced below the inflaming temperature of the body, the combustion ceases.

When a flame is surrounded with a cold thick metallic ring, it is extinguished. If a lighter ring be employed, that does not carry off the caloric so rapidly, it will continue burning slowly; as the ring warms, the combustion will become brighter, and as the heat of the ring is increased, the air may be gradually rarefied, without extinguishing the combustion. It appears, upon the whole, that in the atmospheric air, about ten miles from the earth's surface, a common candle could not burn; at thirteen miles, hydrogen would be incombustible; and at sixteen, sulphur;—phosphorous burns in the most perfect air-pump vacuum that has been produced,

The condensation of air, by extraordinary pressure, does not appear to increase its combustible power. In atmospheric air, condensed into $\frac{1}{2}$ of its volume, iron wire, or charcoal, do not burn more rapidly, nor more brightly, than in air of the usual density.

The agency of atmospheric air in combustion, is affected by the admixture of certain bodies. Thus the addition of

$\frac{1}{10}$ of fluo-silicic acid, or of $\frac{1}{6}$ of muriatic acid, prevents the combustion of a candle in it.

Article 3. Of Chlorine.

§ 1. *Of the Properties of Chlorine.*—Chlorine is a chemical element, which exists in great abundance, combined with other bodies, but naturally does not exist uncombined. The most abundant source of it is the salt that impregnates the ocean, and which, from its abundance and general use, is called common salt.

Chlorine was discovered as a distinct body by M. Scheele in the year 1774; he seemed to consider it as a simple body. Its simple elementary nature has since been more clearly established, and its properties explained, by the labours of Sir H. Davy.

To obtain it, pour upon 8 parts of muriate of soda, previously well mixed with 3 parts of black oxide of manganese, and put into a retort, 4 parts of strong sulphuric acid, diluted with as much water. The chlorine is gradually given out on the application of a gentle heat, and may be received over water, and from thence transferred into bottles. It is a yellowish green transparent gas; it has a peculiar smell, and is extremely irritating and suffocating to the lungs. Its specific gravity, atmospheric air being 1, is 2.5; 100 cubic inches, weigh nearly 76.25 grains. The weight of its combining atom is 36.

When exposed to cold in its usual hygrometric state, crystals are deposited, consisting of the hygrometric water, and a part of the chlorine; similar crystals are formed in abundance, by passing chlorine through water, cooled to about 36° or 40°. They are of a yellowish colour, and volatile. They appear, according to Farraday, to consist of chlorine 27, water 73. When artificially dried it bears an intense cold unchanged: but it is said to be condensed by the cold produced by the evaporation of liquid sulphur-

ous acid. It may be condensed by a pressure, (according to Mr. Farraday,) of about four or five atmospheres, into a deep yellow liquid, which is heavier than water.

When exposed, by Davy, to the most intense action of galvanic electricity, between charcoal or platinum points, it underwent no change.

It is attracted to the positive pole from all its combinations. The force of its attraction for most of the chemical elements is superior to that of oxygen; but the order of its attraction is not quite the same. It decomposes, in consequence, most of the primary compounds of oxygen; but, in consequence of its strong attraction for hydrogen, its compounds are, in their turn, readily decomposed by double attraction, whenever water is present.

The flame of a burning taper immersed in it assumes a red colour, a rapid combustion follows, and a dense smoke is emitted. Phosphorus instantly takes fire in it. Most of the metals, when introduced in the state of foils, or of powder, take fire, and are consumed.

Its compounds with different bodies are called chlorides or acids, according to their properties.

Dried chlorine does not affect vegetable colours; but, on the addition of a little water it destroys them.

At the temperature of 60° Fahrenheit, water dissolves, or condenses, nearly twice its volume of this gas. As the temperature is lowered, it dissolves rather more, but it is given out again when the temperature is raised. This solution may be boiled in a covered vessel, without any chemical change being produced; but, if exposed to the solar rays, a part of the water is decomposed. When this solution is made a part of the galvanic circle, a portion of the water is decomposed; the oxygen and the chlorine are both attracted to the positive pole, and the hydrogen alone to the negative. When an oxidable metal is thrown into this solution, a portion of the water is decomposed by double

attraction, the metal attracting the oxygen, the chlorine the hydrogen, and a muriate of the metal is produced.

When steam is passed with chlorine through a red hot tube, it is decomposed: the chlorine combines with the hydrogen, and sets the oxygen free.

Chlorine is used extensively in bleaching, for which purpose it is generally released from certain compounds at the moment of its action.

It is one of the best agents known for disinfecting the air, and also buildings and apartments, from human contagion and putrid effluvia.

Chlorine may be combined with oxygen in four definite proportions: two of these compounds are oxides, and two acids.

§ 2. *Protoxide of Chlorine.*—Protoxide of chlorine, (the euchlorine of Davy,) is produced by pouring upon a few grains of oxymuriate, or chlorate of potassa in a retort, a small quantity of muriatic acid. On the application of a gentle heat, a deep yellowish green transparent gas comes over, which must be collected over mercury.

It appears to be a chemical compound, consisting of 1 atom of chlorine + 1 oxygen: the volume being condensed $\frac{1}{6}$.

When, at the Royal Institution, chlorate of potassa was decomposed by sulphuric acid, in a bent and sealed glass tube; on the whole being cooled to 0° Fahrenheit, and then distilled at 100°, a very limpid deep-yellow transparent fluid came over, which, on breaking the tube, evaporated with great force.

Its smell somewhat resembles burnt sugar mixed with chlorine. It is readily decomposed with explosion by a gentle heat, or by the addition of various metals, which take fire in it, and burn with brilliancy. It destroys vegetable colours. This compound has no action upon copper leaf; but if a little nitrous gas be added, it is decomposed,

and the oxygen abstracted; and then the chlorine and copper combine with combustion. So that, in this case, we see the presence of oxygen prevent combustion.

§ 3. *Deutoxide of Chlorine.*—Deutoxide of Chlorine is obtained by mixing chlorate of potassa with as much concentrated sulphuric acid as will produce a mass of a bright orange colour, and then exposing it, in a small glass retort, immersed in a water bath, to a temperature very slowly and gradually raised; the gas, as it is distilled, may be received over mercury. Its colour is a more brilliant yellow than that of the last-named compound; its smell is rather aromatic, but resembling chlorine. Water dissolves about 7 volumes, acquiring an orange tint, and an astringent corrosive taste. This gas also destroys vegetable colour; it appears to consist of chlorine 1 atom = 36, + oxygen 4 atoms = 32, = 68. It explodes with violence upon the application of a gentle heat, and is decomposed. It is not decomposed at the atmospheric temperature by any combustible body, phosphorus excepted. Its solution in water is decomposed by the solar rays.

§ 4. *Chloric Acid.*—Chloric acid may be obtained by precipitating chlorate of baryta by sulphuric acid diluted; the chloric acid is left diluted with water.

This solution has neither smell nor colour; it reddens [illegible] paper, and then bleaches it, and has an acid taste. [illegible] may be concentrated by a very gentle heat, until it has more consistence than water. It bears exposure to air and light at a low temperature. Muriatic acid causes a double decomposition; water is produced, and chlorine evolved. It does not precipitate nitrates of silver, mercury, or lead. Such metals as decompose water, decompose this acid. It is judged to consist of 1 atom chlorine = 36, + 5 atoms oxygen = 40, = 76; but it has not been produced except in combination with water.

§ 4. *Perchloric Acid.*—Perchloric acid may be produced

by pouring upon perchlorate of potassa, in a small retort, an equal part of sulphuric acid, and applying heat. It can be procured only in combination with water, or with an alkali. It is supposed to consist of chlorine 1 atom = 36, + oxygen 7 atoms = 56 : = 92.

Chloric and perchloric acids are remarkable for the numerous atomic proportions of oxygen they contain.

Article 4. Iodine.

§ 1. *Of the Properties of Iodine.*—This singular body is an undecompounded chemical element; it exists in very small proportion, having been found in certain sea-weeds only.

It was discovered by accident about twelve years ago, by M. Courtois of Paris, in consequence of its action upon the metallic vessels employed in purifying soda obtained from the ashes of sea-weeds. It was first minutely examined by M. M. Davy and Guy-Lussac. The chemist obtains it from the mother water which is left after crystallizing the soda obtained from kelp. This liquid is concentrated, sulphuric acid, diluted with its volume of water being added in excess, it is boiled, decanted, and strained. It is then put into an alembic, with as much black oxide of manganese as is equal to the weight of the sulphuric acid. On applying heat, a blue vapour rises, and is condensed in the head of the alembic, which is to be kept cool.

The iodine thus obtained, is in small shining plates of a dark colour. Sometimes the plates are rhomboidal, and larger and more brilliant than at others. It is friable and soft, very acrid to the taste, and highly poisonous; in smell it is similar to diluted chlorine; it destroys vegetable colours, and turns them yellow. Its specific gravity is 4.946. It stains the skin of a yellow colour, which gradually disappears. It is soluble in about 7000 parts of water, producing

a yellowish solution. It is extremely volatile, and if exposed to the air wholly evaporates. At about 80° Fahrenheit, or lower, its peculiar coloured vapour begins to appear; and, as the temperature increases, it evaporates more rapidly. It fuses at about 230°, and at about 350° evaporates with great rapidity. It may be distilled with water.

The specific gravity of its vapour is 8.678 compared with atmospheric air; it is a non-conductor of electricity. It is electro-negative with all bodies except chlorine, and probably oxygen. It is soluble in ether, and in alkohol. In its chemical properties, and in many of its compounds, it demonstrates a strong analogy with chlorine. It has, like chlorine, a strong attraction for hydrogen, and forms an acid with it. It combines with less energy than chlorine does. The iodides, like the chlorides, decompose water, when added to it, producing hydriodates. Its atom is estimated at 125. Its vapour combines silently with some combustible bodies; with others the combination is attended with heat, and in some cases with combustion. It is remarkable for producing a deep blue colour in a solution of starch. It combines with oxygen in two proportions, producing acids.

§ 2. *Iodous Acid.* Iodous acid is produced, according to Sementini, a Neapolitan philosopher, by triturating together equal parts of chlorate of potassa and iodine until perfectly mixed. On exposing the mixture to heat in a retort, luted to a receiver, communicating with a pneumatic trough; after a few violet vapours, dense yellow fumes arise, and are condensed into a yellow liquid, of a thick oily consistence. Its taste is acid, and astringent, leaving a burning sensation on the tongue. Its odour, which is disagreeable, somewhat resembles chlorine. It reddens vegetable blues, but does not destroy them. It is volatile, rising rapidly at 112°. It is soluble in water and alkohol. It is decomposed by sulphur

and sulphurous acid: potassium combines with it, with inflammation: phosphorous decomposes it with a noise, as of ebullition, and violet vapour appears.

§ 3. *Iodic Acid.* Iodic acid may be thus obtained: mix a certain quantity of chlorate of potassa and sulphuric acid, as for the preparation of protoxide of chlorine, and put it into a small retort, with a long neck, into which a little dry muriate of lime may be introduced. Adapt to this a tubulated receiver, containing as much iodine as is equal to half the weight of the chlorate of potassa, and apply a gentle heat to the retort. The oxide of chlorine, as it comes over, is decomposed: a recombination takes place, and two compounds are produced—iodic acid, and chloriodic acid; the latter evaporates at a gentle heat, and may be condensed in a receiver, leaving the iodic acid pure.

It is white, solid, semitransparent, and inodorous. It has an astringent acid taste, is slightly deliquescent, and very soluble in water: it is heavier considerably than sulphuric acid, and melts on a slight increase of temperature. It reddens, and then destroys vegetable colours, leaving them of a dull yellow. It is, probably, composed of iodine 1 atom = 125, + oxygen 5 atoms = 40: = 165.

§ 4. *Chloriodic Acid.*—Is obtained in the last process. With chlorine iodine appears, from the experiments of M. Guy-Lussac, to be capable of producing two compounds, strongly resembling each other; but their distinctive properties have not been well ascertained.

When iodine is exposed to the action of chlorine gas, it absorbs nearly one-third of its weight, as was first pointed out by Davy, and becomes a deep orange-coloured crystallized deliquescent body, which is very soluble in water. It is thought to contain iodine 1 atom = 125, + chlorine 1 atom = 36: = 161.

When a great excess of chlorine is passed over iodine, the latter becomes more strongly impregnated, and of a

bright yellow colour. On the other hand, chloriodic acid, or its solution, is capable of dissolving a considerable proportion of iodine.

PART 3. *Of Electro-positive Acidifiable Elements, and their Combinations with the Electro-negative Elements, and with each other.*

ARTICLE 1. GENERAL REMARKS.

These elements all combine energetically, with one or more of the preceding bodies, generally producing acids. When their combinations with them are decomposed by electricity, they are attracted to the negative pole. When their combinations with the electro-negative bodies are energetic, combustion is generally produced. They combine with each other, in some cases producing acids.

ARTICLE 2. OF HYDROGEN.

§ 1. *Of the Properties of Hydrogen.*—Hydrogen is one of the constituent elements of water. Therefore it exists in combination in great abundance, through the world. It is a component part of nearly all vegetable and animal bodies. It is found combined in various bitumens and coals also. From coals it is frequently liberated by natural decomposition, more or less combined with charcoal, producing the fire-damp so frequently fatal to colliers. The chemist obtains it by decomposing water; this may be done in various ways.

When zinc or iron, reduced into small pieces, is put into a flask or retort, and covered with sulphuric acid diluted with five or six volumes of water, this gas is liberated abundantly, and may be received in glass if inverted over water. To render it pure it should be washed in a solution of pure potassa or lime, and then in alkohol. Pure hydrogen gas has neither taste nor smell; but a disagreeable

smell is produced by its gaseous combinations with some of the most inodorous bodies.

This gas is the lightest of the material chemical elements, and indeed of all known bodies; 100 cubic inches of it, when dried, weigh only 2.118 grains; to oxygen its weight is as 1 to 16, or as 0.0694 to 1. Its smallest combining proportion, or atom, is lighter than that of any known body. If, as is probable, the atoms of gasses are of equal volume, the weight of its atom, in relation to oxygen, would be as its specific gravity. But, as is already stated, its atom is assumed to be of twice the volume of an atom of oxygen. Oxygen being unity, therefore, hydrogen is 0.125; or hydrogen being unity, oxygen is 8. It is soluble in about 50 volumes of water. A burning taper, introduced into it is instantly extinguished, but if a jet of oxygen gas be discharged into a balloon filled with hydrogen, it continues burning, and evolves a great proportion of caloric.

It burns in the atmosphere with a feeble blue flame, and great heat. When inflamed as it issues from the flask in which it is evolved, it forms what is called the philosophical candle. Philosophical fire-works are produced by this gas, impregnated with different bodies, and impelled through tubes with varied apertures.

It is not hurtful to the lungs, and therefore it may be respired for a short time, by a man whose lungs are full of atmospheric air; for, as the quantity of air expelled from the lungs, although variable, rarely exceeds one-eighth of their contents, in ordinary respirations, it is some time before the remaining volume is too much diluted for respiration. If a forcible expiration be previously made, then, after three or four respirations, great oppression of the chest is produced, the voice is changed to a squeaking tone, and great general weakness pervades the whole system.

When long narrow hollow cylinders of glass are held perpendicular over an inflamed jet of hydrogen, the passage

of the air and vapour through them produce prolonged musical tones, the note varying with the size of the cylinder.

When two volumes of this gas are mixed with one of pure oxygen, on the application of a bright red heat; such as an electric spark, or of a small portion of platinum powder, to any part of the mixture; the whole of it is inflamed, combines with an explosion, and is instantly condensed into water. When the mixture is rarefied to 16 times its volume, by lessening the atmospheric pressure, the same effect is produced.

Hydrogen therefore forms a good eudiometer for examining the purity of oxygen; the quantity of it that may be present in atmospheric air; and its presence or quantity in any other gas.

To examine atmospheric air, for instance, two measures of hydrogen may be mixed with four of the air in a graduated jar; and a minute bit of porous platinum, an iron wire at a white heat, or an electric spark, will produce an explosion. Of the gas that disappears $\frac{1}{3}$ is oxygen, and $\frac{2}{3}$ hydrogen.

In consequence of the intense heat produced during this combustion, a mixture of these two bodies in the above proportions propelled through a small orifice is applied by chemists as a blow-pipe. The oxy-hydrogen blow-pipe, when so constructed as to prevent accidents, is a most useful instrument of analysis, in the small way, where heat is required. It is capable of producing a degree of heat equalled only by a powerful voltaic battery.

The small specific gravity of hydrogen, compared with that of atmospheric air, has occasioned its application to aeronauncy. A cubic foot of atmospheric air, at the usual temperature and pressure, weight about 527 grains. A cubic foot of hydrogen, about forty grains. The difference, about one ounce for each cubic foot, is nearly the force with

which a balloon would tend to press upwards, if the covering had no weight. A balloon, twenty-five feet in diameter, would contain above 8180 feet of air, and would therefore carry about 512lb. including the weight of the covering.

A peculiar property has lately been discovered by M. Dobereiner, professor of chemistry at Jena: viz. When a bit of porous metallic platinum, prepared by exposing the ammoniaco-muriate of platinum to a red heat, is introduced into a vessel containing a mixture of oxygen and hydrogen, its temperature rapidly increases to a white heat, when the gasses explode and combine into water. It is therefore an useful assistant in the eudiometry of these gasses. When a jet of hydrogen passes through a plate of air, so as to mix with a small portion of oxygen, and then strikes upon a bit of porous platinum, the metal soon becomes of a white heat, and inflames the jet of hydrogen. What part the platinum acts in this phenomenon is unknown; it does not combine with either of the gasses, nor undergo any apparent change. In eudiometry it is found extremely convenient: it is made into little pellets with pipe-clay; and they may be conveniently fixed upon small wires.

§ 2. *Of Water.*—It has been proved repeatedly in a variety of synthetical and analytical experiments, that water is a compound body, and that it is constituted of two volumes of hydrogen to one of oxygen: or hydrogen 1 atom = 1, + oxygen 1 atom, = 8: = 9. When the mixture of these two gasses is left at a low temperature, no action ensues. When the temperature is raised so high as to approach ignition, they combine with tolerable rapidity; little heat is observed, and no light. When a bright red heat is applied, they, as was before observed, combine instantaneously with a violent explosion, a brilliant light and intense heat.

Water may be decomposed and reduced into its elements again, in a variety of ways. By passing the vapour of water over burning charcoal, or red-hot iron, the carbonic acid, or

protoxide of iron thus produced, has the same weight that the elements had when separate; and with the weight of the hydrogen exactly equals the weight of the water, and decomposing body before the experiment.

Water is decomposed during the solution of many metals in sulphuric, and some other acids, the oxygen being separated by the complex attraction of the metal to the oxygen, and of the oxide to the acid. Electricity, as has been shewn, also decomposes water. Indeed, the real composition of water is clearly proved, both by synthesis and analysis, varied in every possible way.

Natural waters, more or less combined, or intermingled with other bodies, occur in immense abundance all over the world, as is well known. By slow distillation it is readily rendered sufficiently pure for ordinary purposes. The more volatile bodies separate first, and those which are less volatile are left in the still. But when water is required for minute, delicate experiments, many precautions are requisite to obtain it perfectly pure; as Sir H. Davy's researches in voltaic electricity sufficiently prove.

Pure water, as is well known, at the usual temperature of this climate, is a very transparent, highly refractive, brilliant liquid; inodorous, and insipid. When slowly cooled in a temperature below 32°, it crystallizes into beautiful needles, crossing each other at angles of 60° and 120°. The irregular expansion of it, from changes of temperature, has been already pointed out. A cubic foot of pure water, at 40°, weighs 999.09 ounces avoirdupoise: a cubic inch therefore weighs 252.95 grains nearly, or at 66°, 252.5. During crystallization, or freezing, it expands so much that the specific gravity of ice is to water as 0.94 to 1. The air that is dissolved in water is expelled during the freezing, and is, more or less, entangled within the substance of the ice, and still further lessens its specific gravity, so that in general, ice in masses is to water as about 0.9 to 1, and, in conse-

quence, when immersed in water, nearly $\frac{1}{10}$ of the mass appears above the surface.

When exposed to an elevated temperature, it has already been shewn that it is converted into vapour, and that its vaporific point is variable with the pressure on its surface. Under the usual barometric pressure of 30 inches nearly, the boiling temperature of water is 212°, and one volume expands into 1694 volumes nearly of steam.

Supposing the specific gravity of water at 60° to be to atmospheric air, of the same temperature, as 820 to 1; the specific gravity of steam at 212°, compared to air at 212°, must be 0.625, or 0.481, compared to air at 60°.

Water is susceptible of a very slight degree of compression when great force is applied. M. Dessaigne asserts that, when great force is suddenly applied it becomes luminous.

Water is a more general agent in chemical phenomena, than any other compound body. A number of bodies have a peculiarly strong attraction for it; and retain it with great force in definite proportions, apparently in an undecompounded state; having their properties at the same time considerably altered and modified by it.

This is the case with a number of acids, many of which cannot, as it appears, exist, unless in combination with water or a base. A great number of the metallic oxides, particularly the alkaline, and earthy, have so strong an attraction for it, as to condense it into a solid; and part with it only at a red heat. Some bodies cannot be separated from it but by the chemical attraction of a third body.

These compounds are distinguished by the name of hydrates. The prefix, hydro, being previously appropriated to compounds with hydrogen only, ought not to be applied to those with water.

The progressive improvement of chemical science, shews that many cases of chemical action occur where water was

formerly considered to be a convenient menstruum merely; but where in reality its elements, by their complicated chemical action, perform the part of principal agents.

A great number of saline bodies, as we have seen, attract a certain quantity of water, and with it assume a definite crystalline form. These crystals are soluble in an additional quantity of water; and generally those salts which contain the largest quantity of water of crystallization, are most soluble. Cold is almost always produced during the solution.

From many of these saline solutions the water may be evaporated at 212°; the solution of carbonate of ammonia has its boiling point much lowered. But in many cases, the attraction of the salt to the water raises its boiling temperature. The following table is abstracted from the experiments of Mr. Griffith, (Journal Royal Institution. No. 36.)

100 parts of Water was saturated with

	Parts.	its boiling point was
Acetate of Soda	60	256°
Nitrate Ditto	60	246
Nitrate of Potassa (common Nitre)	74	238
Rochelli Salt	90	240
Tartrate of Potassa	68	234
Muriate of Ammonia	50	236
Muriate of Soda, or common Salt	30	224
Sulphate of Magnesia, or Epsom Salt	57.5	222
Subcarbonate of Soda		220
Alum	52	220
Sulphate of Iron	64	216
Sulphate of Soda	31.5	213

It was expected, naturally enough, that the most deliquescent salts, and those which dissolved in the largest proportion of water; since they demonstrated the strongest attraction for it, would increase its boiling temperature the most; but, as may be seen from the cases above quoted, this expectation was not verified.

Water intermixes in the state of vapour with all gasses which are exposed over it, as has been stated, affecting the specific gravity in proportion to the quantity of vapour present. Those gasses that are heavier than steam, have their specific gravity diminished; hydrogen being lighter than steam, has its specific gravity increased.

Different dry bodies, such as insoluble minerals, and most vegetable and animal bodies, chiefly when reduced to powder; have an attraction for this hygrometric water, and attract it from gasses, or atmospheric air in different degrees, according to their attractive power, their previous dryness, or the hygrometric state of the gas.

As water passes through the earth, or over its surface, it, of course, acts upon such soluble bodies as lie in its course. Thus are produced the different varieties of spring water, and the difference between them and rain, river, and stagnant water. When water passes over soluble minerals, it dissolves a portion of them, and produces the various medicinal and other mineral waters.

By chance, spring water is extremely pure; generally, however, it contains a portion of sulphate of lime, sometimes carbonate of lime, frequently muriatic salts. These impurities do not always hurt the appearance of the water, but frequently render it unfit for various domestic uses; curdling soap, and communicating a peculiar flavour to tea and other mixtures. Rain and river waters are free from these inconveniences, and when filtered are equally beautiful to the eye. The hardest water, however, may be rendered good for washing and some other uses, by dissolving

a small portion of common pearlash or soda in it, and leaving it a few hours for any precipitate to settle.

Spring water usually contains a portion of air in solution, generally from $\frac{1}{50}$ to $\frac{1}{10}$ of its volume, which communicates a slight briskness to it. It appears to attract the oxygen with rather more force than the nitrogen. To deprive it of the whole of its air, it requires boiling for at least two hours.

Some of the mineral springs are impregnated with different compound gasses.

§ 3. *Of Peroxide of Hydrogen, or Oxygenized Water.* —It has been supposed, until lately, that hydrogen combined with oxygen in one proportion only. But M. Thenard has shewn, that water may, by a certain treatment, be combined with an additional proportion of oxygen. Deutoxide of barium is dissolved in water, and the barium being separated by sulphuric acid, falls down as a protoxide; while the oxygen thus liberated unites to the water. This oxygenized water may be concentrated by evaporation in an exhausted receiver. During the evaporation, water only escapes. When concentrated as much as it will bear, it appears to consist of 1 atom water 9 + 1 oxygen 8 = 17. Each cubic inch having absorbed 662 cubic inches of oxygen, is expanded to 1.3; each volume consequently containing above 1000 volumes of oxygen, and as much hydrogen condensed into it.

It is a colourless, inodorous liquid. It irritates the tongue, and has a strong metallic taste. Applied to the skin, it irritates, corrodes, and whitens it. Its specific gravity is 1.452. When poured into water it falls to the bottom, but it eventually mixes with it. It does not freeze on exposure to severe cold. The additional charge of oxygen has a strong tendency to escape. To preserve the compound it must be kept surrounded with ice.

When the temperature of the liquid increases, the gas has

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a strong tendency to escape with effervescence, and it tends to escape more rapidly as the temperature approaches to 212°. This effervescence is stopped at its commencement by the addition of an acid.

This compound is decomposed by most of the metals in a state of division, or by their oxides, frequently with violence. Dropped on oxide of silver an explosion follows. The protoxides of manganese and cobalt, the oxides of lead, platinum, gold, iridium, palladium and rhodium produce the same phenomenon. In these cases the oxygen of the water is disengaged, and sometimes that of the metal also; but generally when the metals decompose this compound, a portion of the oxygen combines with them. Gold when finely divided acts with great force on it; but no action is produced if a little sulphuric acid has been added. It may be united to muriatic nitric and sulphuric acids; when it affects and modifies their peculiar properties. It appears to act on the metallic sulphurets and to convert them into sulphates.

M. Thenard in consequence found it a valuable instrument in recovering the colour of white lead in some valuable paintings where it had been blackened by long exposure to the air.

§ 4. *Of the Combination of Hydrogen with Chlorine.*—These two elements combine together in equal volumes producing the well known compound called the hydrochloric, or muriatic acid, or spirit of salt.

When equal volumes of these two gasses are put together and kept in a dark place, or even exposed to the light of a common fire, they combine very slowly. If exposed to red heat, the electric spark, the solar light, or to one of the prismatic colours, particularly to the blue or violet; or even if exposed to the light produced by a strong voltaic battery, they combine with rapidity, or even with explosion. When exposed to day-light, in the shade, they combine silently, without the apparent evolution of light or

heat. If a jet of inflamed hydrogen be exposed in chlorine it burns and produces this gas. In the combination of these gasses no change of volume is produced. The specific gravity is consequently the mean of the two bodies; or 1.284, atmospheric air being 1; 100 cubic inches weigh 39.2 grains nearly. It is composed of hydrogen 1 atom, = 1, + chlorine 1 atom, = 36; = 37. This gaseous acid is a transparent, permanently elastic fluid, under the usual atmospheric pressure; but when, in the laboratory of the R. I. it was evolved from muriate of ammonia by sulphuric acid under great pressure it assumed a liquid state. It was of an orange colour, lighter than sulphuric acid, and evaporated with rapid violence on the pressure being removed. The pressure required was *supposed* to equal forty atmospheres.

It has a peculiar irritating pungent smell, and an acid taste; and is corrosive and suffocating to the lungs.

It has a very strong attraction for water, by union with it an instantaneous condensation follows. On escaping into the atmosphere it instantly attracts the hygrometric water, and condenses with it into a white cloud. An inflamed taper is instantly extinguished by it, the upper part assuming a greenish hue. In passing sparks through a confined portion of this gas, Dr. Henry found that a part of it becomes decomposed, but that when the decomposed part exceeds one-thirty-fifth of the whole, a recombination ensues. When passed through a red-hot tube with oxygen, or when exposed with it to the electric spark, water and chlorine are produced. So strong is the attraction of this gas for water, that a few drops of water let into a large jar full of the gas, condenses it, in an instant, with a considerable evolution of caloric. A lump of ice immersed in a sufficient quantity of this gas, is dissolved as rapidly as in boiling water.

One volume of water at the temperature of 40° absorbs

about 480 volumes of this gas; and is increased in volume to 1.436, forming liquid muriatic acid. Acid of this density has the specific gravity of 1.21; 100 parts containing 40.8 of gas. In mixing the concentrated liquid with water a small condensation is produced, and an inconsiderable evolution of caloric. The following Table of the strength and specific gravity of this acid, is from Sir H. Davy. At the temperature 45° — barometer 30

100 parts of muriatic acid		
of the specific gravity of	1.21	contain . 42.43 of gas
	1.20	. . . . 40.8
	1.19	. . . . 38.38
	1.17	. . . . 34.34
	1.16	. . . . 32.32
	1.14	. . . . 28.28
	1.10	. . . . 20.20
	1.05	. . . . 10.10
	1.04	. . . . 8.08
	1.03	. . . . 6.06
	1.02	. . . . 4.04
	1.01	. . . . 2.02

Liquid muriatic acid is economically and conveniently obtained by decomposing common salt. For this purpose, three parts of common salt may be introduced into a tubulated glass retort, and two parts of sulphuric acid previously diluted with one-third part of water may be added gradually: two-thirds of a part of water put into the receiver that is luted to the retort will condense the gas as it comes over. When necessary, a gentle heat must be applied and slowly raised.

Liquid muriatic acid is nearly colourless when pure. When exposed to the atmosphere a portion of gas escapes, and condensing with the moisture of the air produces white fumes. Muriatic acid and the compounds into which it enters are used extensively in chemistry and in various arts,

§ 5. *Of Hydriodic Acid.*—Hydrogen and iodine do not act with great force upon each other. When heated together the hydrogen expands in volume, and an acid gas is formed which is strongly analagous to muriatic acid gas.

It is best obtained by putting to four parts of iodine one of phosphorus in a small glass retort; adding a few drops of water occasionally, and after a time applying a gentle heat. It is an invisible gas, it resembles muriatic acid in smell, and has a sharp sour taste: 100 cubic inches weigh about 132.4 grains. Its specific gravity compared to atmospheric air, is 4.34. It is difficult to preserve it in a gaseous state.

It is rapidly decomposed when heated with oxygen which attracts the hydrogen. Chlorine also attracts the hydrogen, sometimes an explosion follows their mixture. Mercury on the contrary attracts the iodine, leaving the hydrogen free.

It appears to consist of hydrogen 1 atom = 1, + iodine 1 atom = 125; = 126. It is absorbed by water and produces a fuming solution, of which the greatest density is 1.7.

The liquid solution is best obtained by passing sulphuretted hydrogen through iodine diffused in water in a Wolf's apparatus. It may then be concentrated and separated from the sulphur by evaporation and subsequent filtration. It may be distilled at about 260°, it readily dissolves iodine. It is slowly decomposed when left open to the air; the oxygen of the atmosphere attracting its hydrogen. It is decomposed by chlorine also, and by sulphuric and nitric acids.

It produces a fine orange precipitate with saline solutions of lead; with solution of peroxide of mercury a red precipitate; and with solutions of silver a white one, not soluble in ammonia.

The liquid acid has no action upon mercury although the gas acts powerfully on it.

When added to those bodies that retain their oxygen by a feeble attraction, both the acid and the oxide are decomposed and water is produced.

Hydrogen at a high temperature appears to be capable of holding several of the metals in solution, potassium in particular, tellurium, tin, bismuth, and zinc.

Article 3. Of Nitrogen.

§ 1. *Of the Properties of Nitrogen.*—This is an abundant chemical element, constituting four-fifths nearly of our atmosphere. It forms also a constituent part of almost all animal matter and of many vegetables. It is readily obtained pure by adding to atmospheric air $\frac{42}{100}$ of pure hydrogen and passing up a bit of porous platina. The oxygen will be attracted by the hydrogen, and combine with it, producing water, and leaving the nitrogen pure. Or a quantity of atmospheric air may be confined for a day or two over a paste composed of iron filings sulphur and water.

It may be obtained from animal flesh also, by the action of nitric acid.

This gas is inodorous and tasteless; it will not support animal life, nor the flame of combustibles. Its specific gravity compared to atmospheric air is 0.9722: 100 cubic inches, weigh 29.65 grains. This singular body is suspected to be a compound; but it has resisted every attempt hitherto made to decompose it, although it has been tortured in every imaginable way; by exposing it to the actions of voltaic electricity and caloric, both alone and with other bodies. Until it be decomposed it must be considered as a simple chemical element.

It constitutes, as has been said, nearly four-fifths of our

atmosphere. But whether it accomplishes any other use than merely diluting the oxygen, and bringing it to that state which is most congenial to animal and vegetable life, is wholly doubtful. Chemists are not united even in the opinion whether atmospheric air is a chemical combination or merely a mechanical mixture of those two bodies.

In its combination with the electro-negative acidifiable bodies it does not excite the phenomena of combustion, and in consequence it has usually been called an incombustible body. It will be seen, however, that it has some remarkable properties; and that some of its compounds, are some of the most inflammable, and explosive bodies with which we are acquainted. It is attracted in its combinations with oxygen to the electro-negative pole.

§ 2. *Of Atmospheric Air.*—We have frequently had occasion to speak of the composition of atmospheric air, and to refer to many of its general properties. Numerous analyses of its composition, and proportions, have been made in samples taken from different quarters of the world, and at different elevations from the surface of the earth. Not only has it been examined in almost every part of Europe; but it has been brought for examination from most parts of the world; from the coast of Guinea, from Teneriffe, from the summit of the Pyrenees, the Andes, and of Mount Blanc.

It has been brought down in air-balloons from the height, it is said, of 22,000 feet. All the examinations may be considered as producing very nearly the same result: they show that it uniformly contains about 79 of nitrogen to 21 of oxygen. Or more particularly: 100 parts of atmospheric air, contain at an average,

77.5 volumes of	Nitrogen	75.55 by weight.
21.	Oxygen	23.32
1.4	Vapour	1.
0.08	Carbonic Acid	0.1

But as has been noticed, the quantity of hygrometric water is always varying within a certain limitation; and in some cases the proportion of carbonic acid has been found to be somewhat increased. Any other addition it may be found to contain is accidental and temporary. Those contingent effluvia that render the air a source of disease are not to be detected by chemistry.

As atmospheric air in consequence of its generality is used as a standard by which to measure the specific gravity of gasses, it is desirable to obtain its specific gravity with great accuracy; and numerous experiments have been made on this subject by various chemists. There is more difficulty and nicety in solving this problem than is generally imagined.

Messrs. Biot and Arago make the specific gravity of the air at 60° Fahrenheit, the barometer being thirty inches to be 0.001220, water being 1; or as $\frac{1}{770}$ of the specific gravity of water at the same temperature.

Mr. Rice, and Dr. Prout, infer that a volume of water must be as 827.5 nearly to an equal volume of air, but this inference appears to be biassed by an hypothesis that yet remains to be proved.

	cubic inches.	grains.
According to the former 100 weigh		30.8 nearly.
According to the latter		30.6 nearly.
According to Sir G. Shuckburg .		30.5
According to Mr. Brande . . .		30.199, being the average of twelve experiments.

§ 3. *Of Protoxide of Nitrogen.*—Nitrogen combines with oxygen in various definite proportions, producing compounds, several of which are remarkable, and some of them very useful.

The protoxide of nitrogen, or nitrous oxide, is obtained by distilling in a glass retort, placed over a lamp, or in a sand heat, at a temperature between 400° and 410° a por-

tion of nitrate of ammonia: the gas which comes over, being collected over mercury, or, if for respiration, over water, should stand some hours to purify. It is an elastic, transparent fluid, with a peculiar, not unpleasant smell, and a sweetish taste.

Water deprived of air, dissolves more than its own volume of it, and when heated, gives it out again unchanged. One hundred cubic inches weigh 46.6 grains: its specific gravity is nearly 1.53. It consists of nitrogen, two volumes, called one atom = 14, + oxygen, one volume atom = 8; = 22, condensed into the space of two volumes.

According to the experiments made at the Royal Institution. Nitrate of ammonia, decomposed by heat, in a very strong bent glass tube, upon being cooled to 0°, and then distilled over with a warmth of 50°, produced a very limpid, colourless fluid, that did not solidify at —10°, and appeared to be compressed with a force equal to about 50° atmospheres at 45°. A taper burns in it with great brilliancy. Most combustible bodies require a higher temperature to burn in it than in atmospheric air. Caution being taken to keep the temperature regulated, both sulphur and phosphorus may be melted, and sublimed in this gas, without inflaming. When phosphorus is introduced ignited, it inflames and burns brilliantly. Sulphur, when introduced in strong combustion, burns with a brilliant red flame. Charcoal, introduced at a bright red heat, burns with increased brightness. Iron wire, introduced at a bright red heat, burns with brilliancy. Hydrogen detonates with it, and decomposes it.

At a red heat, part of the nitrogen is separated, an increase of volume ensues, and deutoxide of nitrogen is produced.

Animals, confined in this gas, die in a short time. But it may be respired during several respirations. It is most conveniently respired from an oiled silk bag, through a to-

lerably wide pipe. The effect is generally curious, but not the same in all persons. A sensation of unusually exhilarating delight and pleasure is felt, that produces a desire to continue breathing it. The mind becomes intoxicated; dancing, laughing, or other ludicrous gesticulations follow; at length the recollection begins to fail, and the pipe falls from the mouth. In general the mind gradually and shortly returns to its usual state. In persons of full habits, or with short necks and large heads, or with any appearance of a strong circulation of blood through the head, this respiration may produce distressing consequences. Attention should be paid to the purity of the gas. It is not pure unless a portion of it dissolve in an equal volume of well boiled water.

§ 4. *Of Deutoxide of Nitrogen. Nitric Oxide.*—It is called also, nitrous gas. It may be procured by pouring upon mercury, or copper filings, in a retort, a mixture of one part of strong nitric acid and six of water. Apply a gentle heat, the gas comes over, and may be collected over water.

It is a transparent, colourless, elastic fluid; insipid to the taste, but suffocating if taken into the lungs. It does not affect the colour of infusion of litmus.

Its specific gravity is 1.04. 100 cubic inches, weigh 31.8 nearly. It extinguishes flame. It is not decomposed by caloric alone; nor does it detonate with hydrogen; but phosphorus and charcoal decompose it at a red heat. When mixed with hydrogen, it tints the flame of it green. It detonates with ammonia, both gasses being decomposed. Metals having a strong attraction for oxygen decompose it also. As it escapes into atmospheric air, it appears in the state of deep orange-red fumes. These are produced in consequence of its strong attraction for oxygen; the instant it escapes into the air, it attracts a portion of oxygen from it, combines with it, and produces nitrous acid gas. It is

sometimes used as a test of oxygen, and as a measure of its quantity. This deutoxide and chlorine, when both are dried, have no action on each other. But when in their usual hygrometric state, the water and the deutoxide are both decomposed; while muriatic and nitric acids are produced. This compound consists of,

Nitrogen, 2 volumes, called 1 atom = 14
Oxygen, 2 volumes, called 2 atoms = 16 } 30

§ 5. *Of Hyponitrous Acid.*—This acid, discovered by M. M. Gay-Lussac and Berzelieus, may be prepared by mixing over a solution of potassa, or soda, confined by mercury, four parts of nitric oxide gas and one of oxygen: a new acid is produced, and absorbed by the alkali, thus forming a hyponitrite.

The elements in the proportions constituting this acid, are held in combination by a very feeble attraction, and on the addition of another acid to attract the alkali, the acid is decomposed.

It consists of Nitrogen, 2 volumes, 1 atom = 14
Oxygen, 3 volumes, 3 atoms = 24 } 38

This acid appears to be sometimes formed in combination with sulphuric acid, forming prismatic crystals which spontaneously give out nitrous-gas.

§ 6. *Of Nitrous Acid.*—When four volumes, or one atom of nitric oxide gas, and two volumes, or two atoms of oxygen, both being dried, are mixed together, they condense into half their bulk, of a deep orange-red coloured gas. It has a strong peculiar suffocating smell, and an acid taste. A candle burns brilliantly in it, and so does phosphorus. Charcoal burns in it, with a dull light. Burning sulphur is extinguished in it. It is composed of,

Nitrogen, 2 volumes = 1 atom = 14
Oxygen, 4 volumes = 4 atoms = 32 } 46
100 cubic inches weigh about 65 grains.

This gas is absorbed by water, or by nitric acid, and appears to become partially decomposed, during the solution, into nitric acid and nitrous gas; as the quantity of gas condensed in the liquid increases, its colour becomes green, and gradually deepens, then blue, and at length of a deep orange-colour. On the application of heat, the gas is partially decomposed, nitric oxide, and nitrous acid escape slowly: the solution begins to boil, it is said, as low as at 80°.

Its saline combinations are called nitrites. Little is known of them, except that they are decomposed by most acids. They can be produced by exposing nitrates to a high temperature, and thus expelling a part of the oxygen: but it is doubtful whether the nitrites thus formed are definite compounds.

The nitrous acid of commerce is the acid next to be spoken of, more or less coloured with this acid gas, which escapes from it in dense fumes.

§ 7. *Of Nitric Acid.*—It may be prepared by mixing five volumes of oxygen with two of nitrogen, and passing through the mixture for several hours, successive currents of electric sparks from a powerful battery. At length the seven volumes are condensed into two volumes of nitric acid gas. Its specific gravity then, must be 3.75 to air; 100 cubical inches must weigh 114.4.

This gas has a strong attraction for water, and is best known in the liquid state, or as hydrated nitric acid.

It is best obtained by the following process. Put three parts of nitrate of potassa into a glass tubulated retort placed in a sand-bath, pour upon it two parts of sulphuric acid. A large tubulated receiver should be adapted, from which a glass tube should be passed into water, and all the apertures be securely luted. The heat applied should be gentle at first, and slowly increased, but so as to keep the receiver cool. Red fumes, and a coloured acid, at first appear; soon

the acid comes over colourless, and continues so till the end of the process. When it is wanted very pure, it may be re-distilled from a small quantity of nitre. By this means, any sulphuric acid that may have passed over, will be retained. Some manufacturers use one part of sulphuric acid to two of nitre, and that quantity is sufficient to convert the whole of the nitre into a neutral sulphate; but the insufficient proportion of water, and the high temperature that is requisite, causes a decomposition of a part of the acid, and the product is a highly coloured acid. When equal parts of nitre and sulphuric acid are used, as much pure and colourless acid comes over as equals $\frac{1}{3}$ of the nitre in weight, and a bisulphate of potassa is left in the retort.

This liquid nitric acid, in its most concentrated state, has usually the specific gravity of 1.5, rarely 1.52, and appears to contain about 23 parts of water, and 77 of pure acid; or according to Dr. Ure 79.7, when the specific gravity is 1.50; that is of pure acid 1 atom 54, water 2 atoms 18. It is colourless, and on exposure to air, exhales a white fume. A fluid ounce of it decomposes 476 grains of marble.

It stains the skin of a bright yellow. It boils at 248° Fahrenheit; a part of the gas escapes, and the remaining liquid acid comes over unchanged, but its specific gravity is reduced to 1.42, and its strength reduced in proportion. When a weaker acid is boiled, a part of the water escapes first, until the remaining acid has obtained a specific gravity of 1.42

The extensive use of this acid, which is always mixed with water, renders it advantageous to be able to ascertain its relative strength in all cases. The following is abstracted from a table drawn up by Dr. Ure.

Specific Gravity.	Dry Acid in 100.	Specific Gravity.	Dry Acid in 100.
1.5000	79.700	1.2826	38.256
1.4910	76.512	1.2705	36.662
1.4820	74.121	1.2523	34.271
1.4700	70.933	1.2402	32.677
1.4600	68.542	1.2212	30.286
1.4500	66.155	1.2019	27.895
1.4424	64.557	1.1833	25.504
1.4306	62.166	1.1709	23.900
1.4228	60.572	1.1526	21.519
1.4107	58.181	1.1403	19.925
1.4023	56.587	1.1227	17.534
1.3945	54.993	1.1109	15.940
1.3833	53.399	1.0993	14.346
1.3732	51.805	1.0821	11.955
1.3630	50.211	1.0708	10.361
1.3529	48.617	1.0540	7.970
1.3427	47.023	1.0430	6.376
1.3323	45.429	1.0320	4.782
1.3216	43.835	1.0212	3.188
1.3110	42.241	1.0106	1.594
1.3001	40.647	1.0053	0.797

On mixing nitrous acid with water, a small condensation is produced, and caloric is evolved. This condensation is greatest when 58 parts by weight of the acid is poured into 42 parts of water. The temperature rises about 80°, and when the mixture is reduced to its former temperature, its volume will be reduced as much as 7.35 per cent. below the medium.

The concentrated acid becomes solid at 42° below 0° Fahrenheit. When at the specific gravity of 1.3, it freezes at 2° below 0°. When its strength is still further reduced, it requires nearly the same degree of cold as at first to freeze it.

At a low temperature, it absorbs hygrometric moisture from the air. An acid somewhat diluted, instantly dissolves snow or ice, producing extreme cold.

When colourless nitric acid is set in the sun, a part of the oxygen is liberated, and a quantity of nitrous acid gas is produced, which remaining in the acid produces deep orange coloured fumes, which characterize the nitrous acid of commerce. This coloured acid somewhat diluted, and mixed frequently with a portion of sulphuric acid, constitutes the aqua-fortis of commerce.

Nitric acid is decomposed by almost all bodies that have any attraction for oxygen, and generally with an abundant evolution of red fumes. These red fumes are frequently produced by the liberation of nitric oxide chiefly, which, although colourless, is instantly converted into dense orange fumes, by combining with the oxygen of the air into nitrous acid.

When its decomposition is sudden and complete, there is generally a large quantity of heat and light produced. Sulphur, and most of the metals decompose it; attracting its oxygen, and giving off red fumes with more or less heat.

Dry charcoal, phosphorus, sulphur, essential oils, ether, and alkohol, are inflamed by it; and burn with great violence. Destructive fires have many times been produced from inadvertently stowing this acid in the vicinity of combustible bodies. The change of temperature, the action of the sun's rays, or the accidental introduction of some slowly acting combustible, a bit of dry wood for instance, has produced an evolution of gas, and burst the bottle containing it.

There is no action between this acid and gold or platina, nor their oxides. Both those metals have a slight attraction for oxygen, but not sufficient to decompose this acid. Muriatic acid has no attraction for these metals, but it has

for their oxides, although not sufficient to decompose water when present; and is therefore equally inert when added to these metals. But when a mixture of the two acids is used, an action instantly commences; the nitric acid is decomposed, an oxide of the metal is produced, and this oxide is dissolved in the muriatic acid. Hence the value of the mixture called nitromuriatic acid, or in common language aqua regia.

Nitrous acid may be united with an additional quantity of oxygen, producing an oxygenized compound that may be considered analagous to oxygenized water.

§ 8. *Of Chloride of Nitrogen.*—When nitrogen and chlorine gasses are simply mixed, they do not combine; but, when a quantity of chlorine is confined over muriate or nitrate of ammonia, in solution, in a temperature of about 70° or 80°, the gas is gradually absorbed, a film is produced on the surface, which slowly becoming thicker, at length falls to the bottom of the solution in yellow globules.

This compound is more suddenly and violently explosive than any other known body. Its appearance resembles a yellow oil: it is not solidified by cold. On exposure to air, it evaporates with a peculiar smell. Its specific gravity is said to be 1.6. It is supposed to consist of nitrogen 1 atom, 14, + chlorine 4 atoms, 144; = 158. A particle not exceeding a head of a pin in size, upon a slight touch produces a sudden explosion, so violent as to shatter a large pan into atoms. The facility with which it explodes is such, that it is dangerous to touch or move it. It may be distilled at a temperature below 160°, but a very slight increase of temperature, causes an explosion. Just touching it with an essential oil, and with a variety of other inflammable bodies, causes it to explode; but some inflammable bodies do not produce this effect,—resinous bodies, for instance, sugar, and most metals. With camphor it ap-

pears to combine. When treated with mercury, the metal unites with the chlorine, and the nitrogen escapes. Water and acids gradually decompose it.

§ 9. *Iodide of Nitrogen.*—Nitrogen, in a gaseous state, does not act upon iodine; but if a solution of ammonia be mixed with a small quantity of iodine, the ammonia is decomposed. Its elements consisting, as will be seen presently, of hydrogen and nitrogen, enter into combination with different portions of iodine, producing hydriodic acid on the one hand, and iodide of nitrogen on the other.

This iodide of nitrogen falls down in the state of a brown powder. It is violently explosive. To collect it, the solution must be decanted, and while yet wet, it must be placed gently in small divided portions, upon unsized paper, and suffered to dry spontaneously. When exposed to the air, it gradually evaporates. It appears to consist of nitrogen 1 atom 14, and iodine 3 atoms, 375; = 389.

§ 10. *Of Ammonia: Hydruret of Nitrogen.*—When hydrogen and nitrogen gasses, ready formed, are simply mixed, no combination follows; but their union is readily effected, by bringing them together at the moment of their evolution from other combinations, or in their nascent state, as it is called. Hence it is generally produced from the natural and artifical decompositions of animal substances. It is sometimes produced when nascent hydrogen escapes into atmospheric air, as when water is decomposed by the rusting or oxidation of iron.

It is obtained abundantly by manufacturers from the decomposition of animal matter; chiefly from horn, hoofs, and bone. They are put into an iron pot, or still, to which is fitted a head and condensing apparatus, and then exposed to a strong heat. A large quantity of ammonia comes over, combined with carbonic acid and water, and a quantity of stinking oil, from which last it is necessary to

purify it. This may be done in several ways, one of which shall be detailed as a good instance of the economical resources of chemistry.

When bones are used, after all the volatile matter is forced off by heat, they are ground into ivory black; or they are burnt in the open air to whiteness, and powdered. The powder is decomposed, for the preparation of phosphoric acid, and phosphorus, or made into cupels, for the refining gold and silver. When horns, hoofs, and softer animal matters, are employed, the animal charcoal which is left, is valuable for many purposes of chemistry, connected with purifying, discolouring, and filtering liquids.

The stinking ammoniacal liquor is digested upon ground plaster of Paris; a double decomposition takes place. The carbonic acid leaves the ammonia, and combines with the lime, forming chalk; and the sulphuric acid, leaving the lime, combines with the ammonia. The soluble sulphate of ammonia is then strained off. The carbonate of lime impregnated with empyreumatic oil, is a good manure.

The solution of sulphate of ammonia may be further purified by filtering it through animal charcoal. It is then mixed with a certain quantity of muriate of soda, or, if it can be obtained, of muriate of magnesia. A double decomposition again takes place; the sulphuric acid leaves the ammonia, and combines with the soda, producing Glauber salts; or with the magnesia, producing Epsom salts; and the muriatic acid combines with the ammonia, producing muriate of ammonia. These bodies are readily separated from each other, by the necessary processes of evaporation, crystallization, and sublimation.

The chemist obtains pure ammonia, by mixing equal parts of the muriate of ammonia, produced as above stated, and of dry lime; putting the mixture into a retort, and exposing it to heat. The ammonia comes over in the state of a permanently elastic fluid, which must be collected over

mercury: it is transparent and colourless. It is very pungent and stimulating to both the taste and smell; it extinguishes flame, and cannot be respired. 100 cubic inches weigh 18 grains; its specific gravity is 0.59. It is composed of nitrogen 1 atom, 14, and hydrogen 3 atoms 3; = 17, condensed into half their volume. It may be condensed into a liquid by a pressure equal to $6\frac{1}{2}$ atmospheres, or by a cold of about 50° below 0° Fahrenheit, mixed with atmospheric air, it is inflammable at a high temperature. A small jet of it burns in oxygen gas, with a yellow flame. It is decomposed by passing it through a red-hot porcelain tube. Several metals, when placed in the tube, promote this decomposition. As they have no attraction for either of its elements, it is probable that they act by their superior power of conducting caloric to it. The best caloric conductors appear to act most powerfully. It explodes by the electric spark, when mixed with oxygen. It has strong alkaline properties, and is attracted to the electro-negative pole. It affects certain vegetable reds and yellows, changing them respectively to blue, green, and brown. It has a great attraction for water; a jar-full of this gas being exposed to water is absorbed in an instant. At the temperature of 50°, water readily absorbs 500 times its volume, under the atmospheric pressure of 30 inches; and is then expanded to nearly a volume and a half, at the same time lessening its specific gravity. In solutions of intermediate strength, the expansion is greater in proportion than in strong or weak solutions. The specific gravity of the concentrated solution is 0.875; but it is difficult to preserve it at this strength, as a large portion of the gas escapes on exposure to the air, and the escape is promoted by elevation of temperature. The liquid ammonia of commerce is, of course, of very variable strength, but its strength may be readily ascertained by finding its specific gravity.

Thus, liquid ammonia, the specific gravity of which, according to Davy, is,

0.875 contains 32.5 of this gas in 100 of the liquid.
.900 . . 26
.9054 . . 25.4 is the usual strength of strong ammonia of commerce.
.925 . . 19.5
.938 . . 15.8
.951 . . 12.4
.959 . . 10.1
.969 . . 9.5.

Dr. Ure has formed a lengthened table for pointing out the specific gravity of this solution.

Ammonia combines with all acids, forming with them saline compounds. It is affected differently by different metals. It produces a solution with oxide of zinc, the oxides of copper, oxide of silver, and with the protoxides of nickel, cobalt, and iron, the peroxides of mercury, tin, platinum, and gold; it combines also with the acids of antimony. In most of these cases it is decomposed; in some fulminates are produced.

Metallic oxides, that have not a strong attraction for oxygen, when exposed with it to a high temperature, produce a double decomposition, and water is produced.

When dried, chlorine and ammonia are mixed, they act upon each other with such force as to produce heat and light; muriatic acid is formed, the nitrogen is set free; the muriatic acid combines with a part of the undecomposed ammonia, forming muriate of ammonia.

A solution of ammonia is recommended for restoring the appearance of gold trinkets, which have lost their colour from wear, by removing a part of the copper from the surface of the alloy.

§ 11. *Of Chlorate of Ammonia.*—Chlorate of ammonia

may be formed by decomposing carbonate of ammonia by chloric acid. It forms needle-shaped crystals, which are soluble in water and alkohol: they have a sharp taste, are volatile, and detonate upon hot coals.

§ 12. *Iodate of Ammonia* forms small crystalline grains which also detonate when heated.

§ 13. *Hydrochlorate, or Muriate of Ammonia.*—This salt may be obtained by the mixture of equal volumes of the gasses ammonia and muriatic acid. They instantly condense into a white solid, containing ammonia atom 17, muriatic acid 1 atom 37 : = 54, to which 1 atom of water, 9 being added, makes 63 of the sublimed muriate of ammonia of commerce.

This salt is soluble in 3½ times its weight of water at 60°, with a considerable production of cold. An additional quantity is soluble in boiling water, and is deposited in crystals as the water cools.

Pure potassa, soda, baryta, strontia, and lime, attract the muriatic acid from this salt; magnesia partially decomposes it, forming a double salt. This salt is used very extensively in chemistry, in medicine, in tinning copper, and in other branches of metallurgy. In Birmingham alone, above twenty tons are used annually.

§ 14. *Hydriodate of Ammonia* may be prepared by mixing equal volumes of hydriodic and ammoniacal gasses; or by decomposing carbonate of ammonia by liquid hydriodic acid.

It crystallizes in soluble cubical crystals, which may be sublimed in close vessels.

§ 15. *Nitrate of Ammonia* may be prepared by decomposing carbonate of ammonia by dilute nitric acid. When the solution is evaporated to a proper strength, at a temperature below 100°, it crystallizes as it cools, in six-sided prismatic crystals: when evaporated at a higher temperature, it produces fibrous crystals on cooling. When

the evaporation is continued so far that it concretes on a glass rod as it cools, it consolidates into a compact amorphous mass. The dry nitrate appears to consist of ammonia 1 atom 17, nitric acid 1 atom 54; = 71 : in addition to which, the prismatic contains 11.23 per cent. of water; the fibrous 8.2 per cent. and the compact 5.7 per cent.

This salt deliquesces in the air; to the taste it is acrid and bitter. The prismatic crystals are soluble in twice their weight of cold water, or in half their weight of boiling water.

When this salt is heated to the temperature of 600°, it is decomposed with explosion; hence the old chemists called it nitrum flammans.

Article 4. Of Carbon.

§ 1. *Of the Properties of Carbon.*—Carbon is a chemical element, which is sometimes met with pure in the mineral state. It exists also in considerable abundance in vegetable and animal matter. The diamond, it is now known, is pure native carbon in crystals. A Duke of Tuscany first discovered that diamond could be burnt. Mons. Guyton discovered, that the result of its combustion in melted nitre was carbonic acid; and numerous experiments in oxygen gas and in atmospheric air, by different chemists, have confirmed the long doubted truth, that diamond is pure carbon in a crystallized state; that it may be burnt in its own caloric, when once raised to a high temperature; and, that the product of its combination and combustion with oxygen is carbonic acid, and nothing else. But M. Biot, from experiments on the refracting powers of bodies, has been led into the opinion, that diamond, from its high refracting power, cannot be pure carbon, and that it must contain at least ¼ of hydrogen to render its refraction proportionate to its density.

Diamond is the hardest of known bodies. It is brittle, and breaks with a foliated vitreous fracture. It is sometimes dark, or tinted of different colours; but when quite pure, is transparent and colourless. Its highly refracting power constitutes its remarkable beauty. It is a non-conductor of electricity. Its specific gravity is 3.5.

When three or four bits of diamond, in a small platina focus, or basket, are placed in a balloon of oxygen gas, and ignited to a white heat by a voltaic battery, combustion begins, and will continue after the electric wires are removed, supporting a brilliant white heat, until the oxygen, or the diamond is so far consumed, that the caloric evolved, being unequal to that dissipated, is no longer able to support the necessary temperature.

The physical properties of common charcoal are well known.

Carbon exists in combination in many minerals. Combined with oxygen, it helps to constitute the earthy carbonates; a very extensive and valuable class of earths, including chalk, marble, Portland, Bath, and Purbec stones, and many others. Combined with hydrogen, it produces pure naptha, and, with the addition of oxygen and other elements, it constitutes the various bitumens and coals. Combined with oxygen, hydrogen, nitrogen, and other occasional elements, it constitutes vegetable and animal matter.

The chemist usually obtains it, according to the different uses it is to be applied to, from coal, from animal matter, and from vegetables. By burning these bodies in close vessels, all that is volatile by heat is evaporated, and a black mass of carbon more or less pure, is left, which is applicable to different arts, manufactures, and uses; according to its texture, and the different nature of its remaining impurities. Thus are produced the cinders, cokes, and animal and vegetable charcoal of commerce.

To obtain carbon perfectly pure, it would be necessary to decompose alkohol, or a pure essential, or fat oil. But the chemist is usually content with the purest wood-charcoal he can obtain. Pieces of charcoal, prepared from light young wood, and freed from bark; or pieces of clean washed cork; or pure lamp-black, must be selected and exposed to a bright red heat, for an hour or two in a covered crucible. When wood-charcoal is used, it may be burnt while buried in clean sand.

The charcoal thus prepared, varies a little according to the previous nature and texture of the wood it is prepared from.

Different woods produce somewhat different proportions of charcoal. Thus—100 parts of

Beech produce	15 parts.
Mahogany	15.75
Lignum Vitæ	17.25
Oak	17.4
Fir	18.17
Box	20.25

Wood-charcoal has the precise grain of the wood from whence it is obtained; and like wood it has degrees of closeness, or hardness; it contains minute proportion of hydrogen, from which caloric cannot separate it, and from $\frac{1}{150}$ to $\frac{1}{80}$ of saline and earthy matter.

Charcoal, thus prepared, when burnt in oxygen gas, produces the same quantity of carbonic acid that diamond does.

It is a good conductor of electricity, and a good non-conductor of caloric. In caloric alone it is infusible, and unchangeable, except that when long exposed to a high temperature, it contracts a little, and hardens. When after this it is exposed to the action of a very powerful electric battery,

a little hydrogen escapes, and a part of the charcoal is slowly volatilized, the remainder hardening so much as to scratch glass.

It is inodorous and insipid, extremely durable, and perfectly insoluble in water, and in the atmosphere. Piles of wood, which were charred on the surface, have been dug up at Venice, which must have been buried 1500 years, and in the Thames, and other places, where it is probable they had been buried longer, the wood beneath was perfectly sound.

Charcoal strongly attracts a small portion of water. When exposed to the atmosphere, it attracts hygrometric water, and air also, to the extent of 10, or even 20 per cent. of which the greater part is water. It absorbs other gasses also; but in proportions varying according to the texture of the charcoal, and according to the nature of the gas. The most dense charcoals are the best absorbents; but by powdering them, their absorbent power is much injured. The charcoal of cork, which is very light and powdery, has scarcely any absorbent power. According to the experiments of Saussure,

One volume of charcoal absorbed of—

	Vols.		
Ammonia	90.	Bicarburetted Hydrogen	35.
Muriatic Acid Gas . .	85.	Carbonic Oxide . . .	9.4
Sulphurous Acid Gas	65.	Oxygen	9.25
Nitrous Acid Gas . .	40.	Nitrogen	7.5
Sulphuretted Hydrogen	55.	Carburetted Hydrogen	5.
Carbonic Acid . . .	35.	Hydrogen	1.75

The water and the gasses are again given out, on the application of heat. It is probable, however, that a part of the oxygen slowly combines with a portion of charcoal, and perhaps, of the hydrogen that may be present.

When charcoal, impregnated with sulphuretted hydrogen, is exposed to atmospheric air, after a short time, the gas is decomposed, the sulphur is precipitated, and water is formed.

It is probable that other compound gasses are decomposed by it. At least it is a powerful destroyer of all offensive, fœtid, or putrid smells or flavours, in animal or vegetable substances, or in water: for this purpose, animal charcoal, thoroughly calcined at a moderate temperature, and which has been preserved in close vessels, appears to be most effective; when burnt at too high temperature it becomes inert. It seems to stop the progress of putrefaction in a remarkable degree, and to arrest and destroy the appearances of it, when heated or boiled with animal or vegetable bodies. Vinegar boiled with it loses its adventitious smell and colour. Ammonia may be purified by it. Rum and brandy distilled from it, part with their peculiar flavours.

It is used in surgery to prevent fœtid smells in certain cases. It is used as a dentifrice to correct the smell produced by decayed teeth. It is the best substance that can be used for purifying and filtering water impregnated with animal or vegetable matter.

It has a very strong attraction for animal and vegetable colouring matter, and, in consequence, discolours their solutions. The experiments of M. Bussy, (Journal de Pharmacie, 1822) shew that, for this purpose, pure animal charcoal, prepared from blood, for instance, which is completely divided, and rendered porous, possesses the strongest discolouring power; and that the more pure the charcoal, and the more completely divided in texture, the stronger it is in its action, as may be seen in the following table of its action upon a solution of Saxon blue, containing one part of indigo in 1000 of the solution.

Equal parts of,	Portion of Solution Discoloured.
Crude Bone Black (Ivory Black)	1.
Vegetable, or Animal Oil burnt with Phosphate Lime	2.
Bone Black treated with Muriatic Acid . . .	1.87
Bone Black treated with Muriatic Acid and Potassa	45.
Lamp Black calcined	4.
Lamp Black calcined with Potassa	15.2
Charcoal of Acetate of Potassa	5.6
Starch calcined with Potassa	10.6
Albumen calcined with Potassa	34.
Gelatine calcined with Potassa	36.
Blood calcined with Phosphate of Lime, and purified by Muriatic Acid and washing	12.
Blood calcined with Chalk, and purified . . .	18.
Blood calcined with Potassa, and washed . .	50.

Generally speaking, charcoal does not appear to decompose the colouring principles, but to combine with them, and render them insoluble, and also to give them out again to a body that has a superior attraction for them. Thus, indigo is given out again, in the above cases, to solution of potassa.

Charcoal, at a high temperature, has a very strong attraction for oxygen, and produces, during its combination with it, a large quantity of heat and light; at a red heat it decomposes water, and most other compounds of oxygen.

It is used extensively for fuel instead of coal, and has not the inconvenience of smoke, in the smelting of iron, which is to be drawn into wire; in the cementation of steel; and in the fabrication of gunpowder, for which purpose the charcoal of particular woods is found to be more peculiarly adapted.

Lamp-black, ivory-black, and most other black pigments, and even black-lead, are varieties of charcoal. Coke is an

impure charcoal, prepared from coal. It is much more dense than wood charcoal, and, in this country, much cheaper; at the same time, it produces an intense heat. It is used in foundries and smelting furnaces generally, in this country. The atom of carbon is estimated at 6.

§ 2. *Of Carbonic Oxide.*—Carbon combines with oxygen in two definite proportions. When carbonic acid is passed through an ignited tube, containing lumps of charcoal, it combines with an additional portion of charcoal, and is converted into carbonic oxide. The same compound is produced by mixing one part of powdered charcoal with five of dried chalk, in an iron retort: or, by heating together in a similar vessel, one part of iron-filings and three of dried chalk. In the latter case, the metal attracts a portion of oxygen from the acid, and converts it into a protoxide, the oxide produced is free from hydrogen.

Carbonic oxide is a transparent gas. It is not respirable. Its specific gravity is 0.9722. 100 cubic inches weigh 29.65. It is composed of carbon 1 atom 6, oxygen 1 atom 8, = 14. The volume of the compound expands into two volumes. It is not acted on by heat, nor by the electric spark. It extinguishes flame and burns in the air with a pale blue light. An iron wire ignited to bright redness inflames it. Two volumes of this gas mixed with one of oxygen may be exploded by the electric spark, and produces two volumes of carbonic acid. Water dissolves one-fiftieth part of its volume. It is not decomposed by sulphur, nor by phosphorus, nor by any of the metals hitherto tried, except potassium and sodium. These at a red heat attract the oxygen, and the carbon is precipitated. Hydrogen decomposes it also at a red heat, and the carbon is precipitated. It does not affect lime-water.

Carbonic oxide combines with chlorine in equal volumes. The two volumes condense into one, and produce a com-

pound that is called chloro-carbonous acid. It has a peculiar odour and is soluble in water. 100 cubic inches of it weigh 106 grains nearly.

This compound condenses with four volumes of ammonia into a peculiar white compound.

§ 3. *Of Carbonic Acid.*—Carbonic acid may be formed artificially, as has been said, by the combustion of diamond or of charcoal. But it may be obtained more commodiously, and purer, by the decomposition of chalk, limestone, or marble.

When sulphuric acid, diluted with five or six times its weight of water, is poured upon a quantity of powdered marble, this gaseous acid is liberated with effervescence; and may be received over water or mercury. If the first portions, which are mixed with the air of the vessels, are suffered to escape, the remainder will be very pure. 100 cubic inches of this gas when dried weigh 46.6 grains. Its specific gravity is 1.525. It is constituted of carbon 1 atom 6, oxygen 2 atoms 16, =22. The oxygen in combining with the carbon suffering no change of volume.

When dry carbonate of lime was decomposed, in a bent glass tube hermetrically sealed, by concentrated sulphuric acid, an extremely limpid fluid was distilled, over that frequently bursts the tube with great violence, and is instantly converted into carbonic acid gas. It appears, according to M. Faraday, to require a pressure equal to about 36 atmospheres at 32° to confine it.

This gas is inodorous, it extinguishes flame, and is not respirable. In consequence of its superior specific gravity, it mixes slowly with the atmosphere; and may readily be poured from one vessel to another. In the same manner when it is generated in wells, caverns, or fermenting tubs, or when it is formed by incautiously burning charcoal in close rooms, it will collect and expel the atmospheric

air. It will infallibly destroy any animal immersed in it. Ignorance of this danger, or inattention to it, is frequently the cause of death to workmen and others.

An amusing plaything is produced by extinguishing burning paper or chips in a jar full of this gas, and observing the peculiar form and appearance of the smoke.

This gas is convenient for killing insects without injury to their structure or colours.

A portion of it is formed during animal respiration, as is readily shown by breathing for a short time a given quantity of atmospheric air confined in an oiled silk bag, or a bladder, and then washing it with lime-water. It is always present in atmospheric air in quantities varying from $\frac{1}{250}$ to $\frac{1}{2500}$ part. It is most abundant in the vicinity of large towns and manufactories; but it was detected in air from the summit of Mount Blanc.

Water, at the common atmospheric temperature and pressure, if previously freed from air, dissolves rather more than its own volume of this gas, and receives from it a brisk acidulous flavour. Indeed it is capable of dissolving a correspondent volume under any pressure; and, as the density of the gas increases with the pressure, the greater the pressure, the greater the quantity of gas that may be dissolved. Thus, a gallon of water under the pressure of the atmosphere dissolves a gallon of gas; under the pressure of two atmospheres the gas is reduced to half its volume, and will be dissolved in half a gallon of water. Under the pressure of four atmospheres, the volume of gas is reduced to two pints, and may be dissolved in an equal volume of water. It is by saturating a weak solution of soda with this gas, under strong pressure, that carbonated soda-water is prepared. Upon removing the pressure, the additional quantity of gas escapes again, as may be expected. If the solution be placed under an exhausted receiver the whole

of the gas escapes rapidly. It is expelled also by heating the solution. When the solution saturated under strong pressure is frozen rapidly, the gas is equally expelled during congelation, and as it cannot escape, it occupies the interstices of the ice which is frozen in a loose disintegrated state.

Carbonic acid reddens blue vegetable colours; as the acid escapes the previous colour is restored. It is attracted by lime-water from its gaseous, watery, and many of its saline mixtures. The carbonates of lime or chalk produced by their combination, being insoluble in water, renders it milky.

It is decomposed by heating it with potassium or sodium which attracts the oxygen, and the carbon is precipitated.

It is partially decomposed by passing with hydrogen through a red-hot tube; water and carbonic oxide are formed. It is partially decomposed by zinc, and as we have seen, in the preparation of carbonic oxide, by iron.

§ 4. *Of the Carbonates of Ammonia.*—1. When gaseous carbonic acid and ammonia are mixed in certain proportions, they condense into a solid crystalline mass, called carbonate of ammonia. It is constituted of carbonic acid 1 atom 22, and ammonia 1 atom 17; = 39.

2. The carbonate of ammonia of commerce is a white hard semi-transparent saline mass. It is obtained by double attraction. Muriate of ammonia is decomposed, by a definite proportion of chalk, and the application of heat, in close vessels.

The carbonate of ammonia is sublimed, and the muriate of lime, not being volatile is left in the mattrass.

This appears to be a hydrate of sesquicarbonate of ammonia, and to consist of carbonic acid 3 atoms, ammonia 2 atoms, water 2 atoms. It has a pungent smell, sharp taste, but is much milder than pure ammo[illegible]

changes temporarily vegetable reds to blue or green, and yellows to brown. It is soluble in four times its weight of water at 60°.

3. A bicarbonate of ammonia may be formed by passing carbonic acid through a strong solution of the sesquicarbonate. If a solution of the sesquicarbonate be left exposed to the air, a portion of the ammonia escapes, and a bicarbonate is left in solution, and may be crystallized by evaporation at a low temperature. It appears to be constituted exclusively of its water of crystallization, of carbonic acid 2 atoms 44, ammonia 1 atom, 17 = 61. It is probable that the sesquicarbonate is not always uniform in its composition, that is, in the proportion of its ingredients, and that it is a mixture of the other two salts.

These carbonates are much used in medicine, and sometimes in baking and cooking; to counteract, an acescent tendency in flour, while the evolution of gas adds to the lightness of the bread. For this latter purpose especially, they are used in making gingerbread.

§ 5. *Chlorides of Carbon.*—The attention of chemists was first called to these compounds by the experiments of Mr. Faraday on olefiant gas, in the Laboratory of the Royal Institution.

1. Charcoal and chlorine, when simply brought into contact, do not act upon each other. But when olefiant gas is mixed with successive portions of chlorine, and exposed to the sun in a balloon containing a little water, the chlorine decomposes it, and combines with both the elements as they separate. Thus it produces muriatic acid and a chloride of carbon. The muriatic acid is absorbed by the water; the chloride is precipitated in the state of a white substance, not soluble in water, and the remainder of the undecompounded gas being suffered to escape, should be well washed and dried in folds of unsized paper. This substance, it appears, is a perchloride of carbon,

containing of carbon 2 atoms 12, chlorine 3 atoms 108; = 120. It has a fragrant odour, somewhat resembling camphor, little taste, and is insoluble in water. Its specific gravity is nearly 2, compared to water. Its refracting power compared to water is nearly 1.58. It is very fusible. If left exposed to the atmosphere it gradually evaporates. At 360° it evaporates rapidly, and is deposited in the state of a crystalline crust. When held in the flame of a lamp, it burns, emitting a reddish flame, acid fumes, and a great deal of smoke. When ignited in pure oxygen, it burns with a brilliant light.

It is soluble in alkohol, and more soluble in ether. Hot saturated solutions in these liquids, deposit, on cooling, beautiful transparent crystals, which are brittle and not very hard, and of which the primitive crystal is an octoedron. It is soluble in volatile and fixed oils.

It is not acted on by chlorine nor by mineral acids, nor alkaline solutions. But it is decomposed by heat, and more readily on the addition of oxygen or hydrogen. Many metallic oxides decompose it at a high temperature.

2. When perchloride of carbon is passed in vapour over pieces of glass in an ignited glass tube, a part of the chlorine separates, and a transparent liquid is produced which appears to be a protochloride of carbon, consisting of carbon 1 atom 6, and chlorine 1 atom, 36; = 42. Its specific gravity is about 1.55. Its refractive power 1.49 nearly. This fluid is extremely limpid and colourless; it is not combustible unless held in flame. Then it burns with a bright yellow light and great smoke. It is converted into vapour at a temperature below 170°. It is not soluble in water, but like the perchloride, it is soluble in alkohol, ether, volatile and expressed oils. Neither is it soluble in acid or alkaline chlorine. It is decomposed by oxygen at a high temperature and by hydrogen; and is acted on by other bodies nearly as the perchloride is.

3. A compound sent from Abo in Finland; where it was produced during the distillation of green vitriol and nitre for the production of nitrous acid; was examined by Messrs. Philips and Faraday.

It is a solid crystalline body, fusible, evaporates when exposed to heat, and condenses into crystals. It is heavier than water, and insoluble in it; but soluble in alkohol, ether, and essential oils. It burns with a red flame, producing a great deal of smoke and muriatic gas. In its other affections it is strongly analogous to the bodies above described, and appears to be a subchloride of carbon consisting of carbon 2 atoms 12, chlorine 1 atom 36, = 48. It has not been formed artificially.

§ 6. *Carburets of Hydrogen.*—1. Hydrogen has no direct action upon solid carbon. But in various cases of natural and artificial combinations, carburets of hydrogen are produced.

The gas that is frequently encountered with so much danger in coal mines and called by the miners, the fire damp, contains these bodies in combination. A combination of them is also met with, in stagnant marshy places, or where vegetable and animal matters are decomposing. The same compound is obtained also in great abundance in the decomposition of animal and vegetable bodies, and of various oils, bitumens, and coals by heat. It forms the basis of the illuminating gasses now in such general use. But in all these cases the gasses are more or less impure, and even when all other impurities are removed, hydrogen and carbon in solution in it excepted, the specific gravities and illuminating properties of different carburets are very variable.

According to the opinion of some chemists, in particular of Mr. Brande, only one definite compound of carbon and hydrogen can be produced by art, and its mixture with different proportions of hydrogen produces the various gasses

we have spoken of. Other chemists are of opinion that carbon combines with hydrogen in several proportions producing gaseous compounds.

This difference of opinion is not easily settled, for no mode of analysis is known that can determine the question. But it is known that various permanent liquid and solid compounds exist, consisting essentially of carbon and hydrogen in different proportions. This could not happen if carbon and hydrogen were incapable of combining in more than one proportion.

2. There is, however, one compound well known called CARBURETTED HYDROGEN, or olefiant gas. It may be obtained pure by heating, in a glass retort, four parts of sulphuric acid, and one of alkohol. Upon the application of a moderate heat the gas comes over and may be received over water. This gas is perfectly transparent, colourless, and free from smell. It is soluble in about seven volumes of water. Its specific gravity is 0.97 nearly. 100 cubic inches weigh 29.65 grains. It is constituted of carbon 1 atom 6, hydrogen 1 atom, 1 = 7 condensed into half the volume of the hydrogen. It burns in the atmosphere with a remarkably dense white brilliant flame which illuminates very powerfully: it is, indeed the most brilliant of all the illuminating gasses the chemist is acquainted with. It consumes during combustion three volumes of oxygen, and produces two volumes of carbonic acid gas, and as much water as one volume of oxygen and two volumes of hydrogen produce.

When sulphur is heated in a volume of this gas, it decomposes it, and combining with the hydrogen produces two volumes of sulphuretted hydrogen.

This gas when mixed with an equal volume of chlorine shortly condenses with it into a hydro-chloride. But if immediately on mixing it, a taper is applied; it will burn, muriatic acid is formed, and the charcoal precipitated;

when a larger proportion of chlorine is employed chloride of carbon is produced.

3. *Subcarburetted Hydrogen.*—When glass vessels, filled with water, are inverted over a stagnant pond, containing decayed vegetable matter, a quantity of inflammable gas may be collected, which, when washed with lime water, appears to be a definite compound of carbon and hydrogen. The fire-damps of coal-pits appears to be a very similar gas in its proportions; and a similar gas is produced by igniting acetate of potash in a gun barrel. This gas is considered by many chemists, as a subcarburetted hydrogen, and appears to consist of carbon 1 atom 6, and hydrogen 2 atoms, 1 2 = 8. When well washed, and freed from carbonic oxide, and other impurities, it has no smell, but as generally obtained, its smell is unpleasant. It burns with a yellow flame, that is very inferior in beauty and density to that of the gas last spoken of. Its specific gravity appears to be 555. 100 cubic inches weigh 17 grains. When exploded with two volumes of oxygen, one volume of carbonic acid is produced, and one volume of the oxygen contributes to the production of water.

When exposed to the action of chlorine gas, in a moderate light, it is quickly decomposed. If the mixture be kept in the dark, the decomposition is effected in three or four days.

M. Berthollet says, he has obtained a carburetted hydrogen, by passing olefiant gas through a tube, in which it was exposed to an intense heat; it was decomposed, and a compound produced that contained two parts, by weight, of hydrogen, and one of carbon. Supposing it to be a distinct compound, and not a mixture of pure hydrogen, with a small quantity of carburetted hydrogen gas, it would be constituted of carbon 1 atom 6, hydrogen 12 atoms 12 : = 18.

4. *Of Natural Bituminous Substances, or Compounds of Carbon, Hydrogen, and Oxygen.*

An extensive class of mineral bodies, some of which are in considerable abundance, are met with in the earth, which are called bituminous, and are known by peculiar characters. They are combustible, of a specific gravity, varying from 0.7 to 2, seldom more, unless impure. They vary in consistence from brittle solids to perfect fluidity, and in colour from black to pale brown and white. In most cases they evolve gasses at an ignited temperature, and, consequently, burn with flame more or less brilliant. Mineralogists, according to their varying physical properties, have arranged the greater number of them under the orders of coals and bitumens. These two orders merge into each other, according to the proportion of the elements they contain.

The principal of these bodies are jet, the various coals, asphaltum, petroleum, naptha, amber, honeystone, elastic bitumen, adipocire, and maltha.

Coals are met with in various parts of the world, generally at a small distance from the surface of the earth. They contain a large superabundant proportion of carbon,—jet, anthracite, and coals, vary much in their appearance and properties, and are, in consequence, divided by mineralogists into a number of species and subspecies.

They are composed chiefly of carbon, united in various proportions with hydrogen; oxygen is an ingredient that is almost always present, and the variable proportion of it strongly effects their characters. Nitrogen also is frequently present, but in comparatively small proportion. They are further variously modified by contingent mixtures, or combinations with sulphur, and various earthy bodies, which sometimes are in large proportion. Coals, in general, produce from 50 to 90 per cent. of charcoal, but occasion-

ally they exceed in both extremes. The proportion in Newcastle coals generally fluctuates about 70 per cent. Those coals containing the largest quantity of pure carbon, produce the best coke; those which contain the largest quantity of hydrogen, combined with the carbon, produce the best illuminating gasses, and in the largest quantity.

In bitumens there is generally less earthy and foreign matter; the proportions of carbon and oxygen are less, and, in consequence, they are more volatile. As the proportions of carbon and oxygen diminish, they become more fluid and paler; and naptha, the purest of bitumens, appears to contain carbon and hydrogen only. When pure, it is a colourless fragrant limpid liquid, which is highly inflammable, whose specific gravity is 0.7, containing, according to Dr. Ure's analysis,

Carbon	83	hydrogen	12.31	oxygen	4.65; or,
atoms	22		20		1.

As the specific gravity of this naptha was 0.857, it appears not to have been pure. Mr. Saussure states the composition of pure naptha to be carbon 87.2, hydrogen 12.8; Dr. Thompson found 100 parts of Persian naptha to contain carbon 82.2, hydrogen 14.8; the remaining 3 parts he *supposes* to be nitrogen. When left exposed to the action of air, it gradually attracts a portion of the oxygen; the compound becomes darker coloured, and less limpid and inflammable.

During the distillation of coals and bitumens for illuminating gasses, a quantity of artificial naptha is produced, which, when rectified, has all the properties of the purest natural naptha.

When the vapour of coal tar is passed two or three times through an ignited iron tube, a snow-white substance is obtained, which, when cooled below 180°, concretes into a crystalline, hard, slightly unctuous mass, which is readily

reduced to a smooth silvery powder. Its flavour is aromatic; its taste pungent and aromatic. When volatilized and slowly cooled, it condenses into flexible crystalline plates. Dr. Kidd, who discovered this body, named it napthaline. According to Dr. Ure's analysis, it is composed of carbon 91.6, hydrogen 7.7, oxygen 0.7; so that it is probably a concrete pure carburet of hydrogen.

The gradual variations that this class of bodies exhibit, while the same elements produce the distinctive characters of the class, from stony and slaty coals, to pure coal, bovey coal, mineral wood, bitumens, and the purest naptha, lead to a probability that the whole of them are derived from one common origin; that they owe their numerous variations, in part, to contingent admixtures with the various bodies surrounding them, and in part to the variable proportions and play of attractions brought into action, and kept in operation for an unknown length of time.

While this class of bodies differs in its elements and properties from all other natural mineral combinations, the same elements are combined in vegetables. The properties of these two classes of bodies are analagous in several respects. When the naturalist traces with attention the structure of different varieties of coal, he finds it, in many cases, strongly approaching to the structure of vegetables. The form of the branches, the shape of the leaves, the peculiar grain even of the wood is so strong, in some cases, as not to admit of a doubt. In unpeopled countries, during the progress of time, enormous quantities of vegetable matter must have successively grown up, have partially decayed, and have been buried under succeeding crops, which have, in their turn, been successively overturned. What has become of all this matter? The probability is, that, in some of the different convulsions of the earth's surface, of which so many traces are left in different parts of the world, large

portions of it have been overturned, and buried, and that subsequent chemical actions have converted it into these bituminous minerals. Upon this subject, Jameson's Mineralogy, and Parkinson on Organic Remains, may be consulted.

5. AMBER is a well-known, beautiful, bituminous mineral, of various shades of orange brown. It occurs in considerable quantity in Prussia, in the vicinity of other bituminous matter. It is hard and brittle, takes a fine polish, and is electric: its specific gravity varies from 1.1 to about 1.06. It melts at 550°. It flames when ignited, and burns with little soot. It is not soluble in water, and very slightly in alkohol. When distilled in a close vessel, a strong smelling oil comes over, at first transparent, but as the process advances becoming more dull and thick. This is called oil of amber. Towards the end of the process a peculiar crystalline body comes over; this is the succinic acid. When purified by solution and crystallization it is in transparent shining prisms. It has an acid taste, and combines with alkalies and metallic oxides, forming a distinct class of salts. Of these the succinates of ammonia, and of potassa, are used as tests of iron; succinate of iron being an insoluble reddish compound.

Amber is constituted, according to D.. Ure's analysis, of carbon 70.68, hydrogen 11.62, oxygen 17.77.

6. MELLITE or honeystone is a crystallized honey-coloured mineral, which is semi-transparent, hard, and brittle, and becomes black when heated in a close vessel. It is composed, according to M Klaproth, of alumina 16, a peculiar acid 46, and water of crystallization 38.

This MELLITIC ACID may be obtained by boiling the powdered mellite in 70 parts of water, filtering and evaporating, when the acid crystallizes in fine needles or prisms, of a slightly acid taste. It is readily decomposed by heat.

It forms brilliant crystals with the alkalies, and with some of the alkaline earths. It appears to combine with most of the saline bases.

7. Mineral Caoutchouc varies a little in its appearance. In colour it is generally dark, it has a greasy feel, and is not so easily acted upon as vegetable caoutchouc, with which in other properties it is analogous.

8. Adipocire or mountain tallow, appears something like common tallow; it is insoluble in water, soluble in alkohol, oil of turpentine, and olive oil, but it is not soluble in alkalies, nor does it form soap.

9. *Of Illuminating Gasses.*—When coal is exposed to a high temperature in close vessels, decomposition commences, and the elements recombining in a different order and proportion, produce new compounds. As the force and order of the chemical attractions vary with the temperature, so according to the temperature at which coal is decomposed do the products obtained vary.

The gas is best adapted for illminating when the distillation is carried on at a cherry red heat. When the temperature is much higher or lower, the gas that is produced gives a more feeble and diluted light.

Coal gas is in all cases a variable heterogeneous mixture of different kinds of gasses. Besides olefiant gas and subcarburetted hydrogen there is usually a quantity of pure hydrogen, a quantity of carbonic oxide, and carbonic acid gasses, of nitrogen, of some of its compounds with oxygen, of ammonia; and, if the coals contained sulphur, from which they are seldom free, a quantity of sulphurous acid and sulphuretted hydrogen are produced. But, the more pure and bituminous coal is, the purer and more abundant the gas; and in consequence, the better the light.

The quantity of gas that may be obtained from a chaldron of different kinds of coal may be seen in the following results furnished by the experiments of Mr. Accum.

	Cubic feet.
One Chaldrorn of Scotch Cannel Coal . . .	19890
Lancashire Wigan Cannel .	19608
Yorkshire Cannel	18860
Staffordshire Coal 1st variety	9748
2 . . .	10223
3 . . .	10866
4 . . .	9796
Gloucestershire High Delph	16584
Ditto . . . Low . . .	12852
Ditto . . . Middle . .	12096
Newcastle Coal, Hartley .	16120
Cowper's Main	15876
Tanfield Moor	16920
Pontops , ...	15112
Russel Walls' End . . .	16876
Bewick's ditto	16897
Heaton Main	15876
Bleyth	12096
Elden Main	9600
Primrose Main	8348

In gas manufactories, the coals are distilled for a certain number of hours. In London the best Newcastle coals are used. The retorts are generally charged every eight hours, and about 10,000 cubic feet of gas appears to be nearly the quantity produced from each chaldron.

The specific gravity of coal gas is very variable. If taken at the estimation of Dr. Henry at 0.676, the weight of the gas from a chaldron of coals appears to be 500 lbs. nearly.

There is perhaps an average of 150 lbs. of tar obtained from each chaldron of coals. The remainder is converted into porous coke, which is increased in volume to nearly

1 ½ chaldron. After the tar is condensed by cold, the gas is washed in a mixture of lime and water. This condenses the carbonic acid and the sulphurous acid: the gas then is considered as fit for use. The gas applied to the western parts of London is still extremely impure, and acts very strongly upon the copper valves and pipes, so that in a short time they become corroded, unserviceable, and dangerous.

The illuminating power of oil-gas seems to be full double that of coal-gas. This is in consequence of the much larger quantity of olefiant gas that oil produces during its decomposition. It has the advantage also of being free from smell, and the disadvantage of being more expensive.

This gas also varies according to the oil it is produced from, and according to the temperature at which it is produced, but not to the extent that coal-gas does.

On an average one gallon of oil will produce about 100 cubic feet of gas, of about .900 specific gravity, of which 10 volumes combine with about 26 of oxygen, producing about 16 volumes of carbonic acid.

The heat evolved by gas is not in the same proportion as the light. Pure hydrogen evolves a large quantity of heat, and very little light. Pure carburetted hydrogen produces a large proportion of light. Carbonic oxide evolves very little light in proportion to the heat. The illuminating value of gas depends upon the quantity of carbon combined with the hydrogen. The greater therefore the specific gravity of the gas, the greater will be found its illuminating power.

The proportion of light emitted by the same gas varies also, according to the temperature at which the combustion is carried on.

§ 7. *Hydrochloride of Carbon.*—When the carburetted hydrogen gas is mixed with an equal volume of chlorine,

over water, the two gasses condense into an oil-like compound. Hence, carburetted hydrogen was named olefiant gas.

This hydrochloride of carbon, when washed and distilled from dry muriate of lime, is a colourless limpid fluid, of a pleasant odour, and a sharp agreeable taste. It appears to be constituted of carburetted hydrogen, 2 atoms 14, chlorine 1 atom 36=50.

§ 8. *Hydriodide of Carbon.*—When iodine is exposed to light in carburetted hydrogen, a combination is produced. This hydriodide of carbon is a white crystalline solid. It has a grateful odour, a sweetish taste, is heavier than sulphuric acid, fusible and volatile. A strong heat decomposes it. According to Mr. Faraday, it consists of carburetted hydrogen, 2 atoms 14, iodine 1 atom 125;=139.

§ 9. *Of Cyanogen or Prussine.*—1. This very singular body, and its compounds, in consequence of the near balance of their respective attractions, and their ready change of composition in obedience to the action of every fresh agent, constitute one of the most obscure and curious subjects of chemistry. They have accordingly attracted the attention of many of the most able and industrious of chemical experimenters. Prussian blue, and some other compounds of hydrocyanic or prussic acid have been known for some time; but their true nature is a recent discovery of M. Gay-Lussac.

Nitrogen and carbon do not act upon each other when mixed. But when pure, perfectly dry cyanide of mercury is distilled in a small glass retort, at a dull red heat, it is decomposed. A peculiar compound of carbon and nitrogen comes over in the state of a gas; the mercury at the same time coming over in a metallic state. This gas, the discoverer has named cyanogen.

It is a colourless transparent gas, with a peculiar pene-

trating smell, that is unpleasant and suffocating. It was condensed into a liquid at the Royal Institution, by a pressure equal to about 3½ atmospheres at the temperature of 45°; it is said by M. Bussey to have been condensed by extreme cold.

Its specific gravity is 1.8, compared to atmospheric air. 100 cubic inches weigh 55 grains. It appears to be composed of carbon 2 atoms, or 12 nitrogen 1 atom, or 14=26.

In its chemical properties it has a strong analogy to the electro-negative bodies, chlorine and iodine; and, if it were of difficult decomposition, would readily be considered as a simple electro-negative chemical element. It bears a red heat before it is decomposed by heat alone; it burns in atmospheric air with a purple flame. Water dissolves between four and five volumes of it, producing an acid tasting solution that temporarily reddens vegetable blues. It is more soluble in alkohol.

When its compounds are decomposed by voltaic electricity, it is attracted, undecomposed, to the positive pole.

When detonated with 2 volumes of oxygen, it is decomposed; 2 volumes of carbonic acid are produced, and 1 of nitrogen evolved. Several phenomena shew that it is capable of combining with oxygen, and that the compound is supported by a weak attraction that is strengthened by the addition of a third element, forming a double compound. But as yet, no definite compound of cyanogen and oxygen has been satisfactorily pointed out.

Iodine, phosphorus, and sulphur may be sublimed unchanged in cyanogen. But when heated with cyanide of mercury they decompose it, and combine with the cyanogen.

Like chlorine and iodine, it combines with hydrogen, producing a peculiar acid. It combines with many of the metals, particularly with the bases of the alkalies and earths, with inflammation, and converts them into cyanides,

which water changes into hydrocyanates of the oxides. It appears to combine with the alkalies and alkaline earth in the manner of an acid.

2. *Of Chlorocyanic Acid.*—Cyanogen combines with chlorine, producing a chloride of cyanogen, or chlorocyanic-acid. This compound is made by passing chlorine through a solution of prussic, or hydrocyanic-acid, until the solution discolours a dilute solution of indigo in sulphuric-acid. The mixture should then be agitated with mercury to separate the excess of chlorine, and distilled at a very low temperature, the receiver being surrounded by ice. A liquid comes over which assumes the state of gas, at about 70°. Or, if the atmospheric pressure be partially removed, it assumes that state at lower temperatures. It appears, from M. Gay-Lussac's experiments, to consist of cyanogen 1 atom 26, chlorine 1 atom 36 = 62 combining without condensation.

Its specific gravity is nearly 2.15. 100 cubic inches weigh about 65.7. It is colourless when liquid, has a penetrating smell, and irritates the membrane of the nose. It is not inflammable, nor does it detonate with oxygen nor hydrogen. It reddens litmus. It does not precipitate nitrate of silver, nor form Prussian blue with iron. The alkalies absorb it rapidly.

3. *Of Iodocyanic Acid.*—Cyanogen combines with iodine, producing a compound which is volatile, precipitates in flocculi, has a pungent smell, and an acrid taste. It may be produced by heating cyanuret of mercury with iodine. Thrown on hot charcoal, it evolves violet vapours.

4. *Hydrocyanic, or Prussic Acid,* may be obtained by mixing equal weights of cyanide of mercury and muriatic acid in a retort, applying an adopter and a receiver, which latter must be surrounded with ice. One-half of the adopter must be filled with lumps of dry chloride of lime,

and the other with lumps of dry marble. Upon applying a very gentle heat, the hydrocyanic acid comes over, and, as it passes through the adopter, is deprived of the muriatic acid and water that may rise with it. A part of the acid condenses in the adopter, and may be removed by applying a cloth round it, that is wet in water, at the temperature of 90° Fahrenheit.

A colourless fluid comes over, that is a most deadly poison. Its smell in this condensed state is very irritating and dangerous; a little diluted it produces nausea and faintness. In a more diluted state it produces the well-known flavour of the cherry laurel, the cleomatis, and the bitter almond. Its cool taste is quickly succeeded by one that is hot and acrid.

Its specific gravity at 44° is nearly 0.706. It appears to consist of cyanogen 1 atom 26 + hydrogen 1 atom 1 = 27. It is very volatile. It boils, and is converted into a gas at about 80°, and may be condensed again by lowering the temperature, or increasing the pressure.

It freezes into regular fibrous crystals at about 3° Fahrenheit, and liquefies again at 5°. When dropped upon paper, a part is instantly volatilized, and the cold produced freezes the remainder. It has a strong tendency to decompose, and cannot be preserved for a few days, unless in the dark, and at a low temperature.

When it is detonated, in a gaseous state, with an equal volume of oxygen, it produces 1 volume of carbonic acid gas, half a volume of nitrogen, and the same of hydrogen. It does not combine with hydrogen. It is decomposed by potassium, which combines with the cyanogen, forming a definite cyanide of potassium, and evolving half its volume of hydrogen.

Its attraction for the alkalies and oxides is very slight. It partially neutralizes them only, and is set free by carbonic

acid. It has a strong disposition to form triple salts, in which the elements have a strong attraction, and these salts are, in consequence, more permanent than the binary combinations.

A single drop of this acid will cause instant death when dropped into the mouth of a small animal. A German professor is said to have died shortly after rubbing his arm with it. Diluted to a certain standard with water, it has lately been introduced into medicine. Various formula are recommended for preparing it pure, and of a known strength, and every one is, of course, the best. It appears, however, to have been recommended, as new medicines mostly are, with more confidence than it deserves.

Its volatility and strong tendency to decomposition, when the atmospheric air and light have access to it, on its being occasionally opened, are the most serious objections to a dependence upon its uniform strength. When pure, whether it be prepared of the strength directed by Scheele, or by Vauquelin, if kept inverted in well-stopped vials, in a cool dark place, it does not change; but, on occasional exposure to the atmosphere, it partly escapes, and is in part decomposed.

According to the experiments of Dr. Ure, the following are the specific gravities of solutions of hydrocyanic acid, of various strengths.

Sp. Gravity.	Real Acid in 100 parts.	Sp. Gravity.	Real Acid in 100 parts.
0.9570	16	0.9958	3.
0.9768	10.6	0.9964	2.7
0.9815	9.1	0.9967	2.5
0.9840	8.	0.9970	2.3
0.9870	7.3	0.9973	2.1
0.9890	6.4	0.9974	2.
0.9900	5.8	0.9975	1.77
0.9923	5.	0.9978	1.68
0.9940	4.	0.9979	1.6

The acids of the specific gravity of 0.996 and 0.997 are generally used in medicine, and the strength of the former is to that of the latter as 2.7 to 2; a wide difference in a medicine requiring accuracy; and yet great delicacy, both in the balance employed, and in the necessary manipulation, is requisite, to determine between them. There is the risk also of their not being pure. Another test has, in consequence, been proposed by the same chemist that is more readily applicable.

To 100 grains, or any convenient quantity, in a small vial, add successively small but known portions of the nitric oxide of mercury, until the acid ceases to dissolve it. The quantity of the powder that has been used, divided by 4, gives the quantity of real acid present in the solution, supposing the solution to be pure.

A solution, containing 2 to 3 per cent. of pure acid, is destructive of vegetation in seeds that are soaked in it.

Article 5. Of Sulphur.

§ 1. Sulphur is an electro-positive chemical element that is well known.

It is found in great abundance in various parts of the world. Sometimes it is found nearly pure; more or less yellow and crystallized, translucent, doubly refractive, hard, and shining; sometimes it is disseminated, massive, earthy, or volcanic. Frequently it is combined with various metals in the state of sulphurets. Large quantities occur also, combined with oxygen, and a base in the state of sulphates. The best sulphur in the English market comes from Sicily.

Pure sulphur is a brittle, pale yellow mineral, capable of crystallizing. The primitive form of its crystal is an acute octaedron. It is inodorous and tasteless, but readily diffuses a peculiar well-known smell on being slightly heated in the air.

At about 180° it begins to melt, and to evaporate slowly; at 220°, or less, it is a limpid liquid; if kept melted for a time in the open air, it becomes viscid and dark-coloured; and if then poured into cold water, it cools into a reddish substance, which is ductile, and of increased specific gravity, and which is convenient for taking impressions of seals, medals, &c. When melted in a close vessel, this change is equally produced.

Roll sulphur is common sulphur melted and cast into moulds. When grasped in a warm hand, it falls to pieces with a slight cracking.

When heated to about 600° in vessels closed from the action of the air, it sublimes rapidly, and by letting it pass into a large chamber, it cools, and falls down in the state of flowers of sulphur. Crystals of sulphur may be readily obtained, by melting it in a deep ladle, and when the surface has cooled, suddenly drawing off the lower part. At about 560 it takes fire in the open air, and burns rapidly, with a pale blue flame, and a strong suffocating sulphurous smell.

Pure sulphur is insoluble in water. The vapour of it is soluble in alkohol, to a small extent. A similar compound is produced, by macerating flowers of sulphur during some hours in hot alkohol.

The purest sulphur that the chemist can produce, always emits a small portion of hydrogen. It seems to be impossible to free sulphur wholly from hydrogen, except by combining it with some other body. When burnt with dry oxygen, a small proportion of water is always produced. When added to potassium, a combination follows, with intense heat and light; and however pure the sulphur, sulphuretted hydrogen is produced. Exposed in a glass tube, by Sir H. Davy, to the action of a strong voltaic circle, by means of platinum wires, violent ebullition was produced, with intense light, and above five volumes of sulphuretted

hydrogen gas were emitted, while the sulphur became of a reddish brown colour.

It combines with metals at a high temperature, and during their combination a quantity of caloric and light is produced. Its equivalent atom is estimated at 16.

Sulphur combines with oxygen in four known definite proportions, producing very different compounds.

§ 2. *Sulphurous Acid* is produced by burning sulphur in atmospheric air, or slowly in oxygen gas; in the latter case, it is mixed with sulphuric acid; the former with nitrogen.

To obtain it pure, sulphuric acid may be poured upon an equal weight of mercury, or tin, in a retort, and heat applied. An effervescence shortly commences, and the gas that is evolved may be received over mercury, or into water. It is in a gaseous state at the usual atmospheric temperature and pressure; but it may be condensed into a liquid by a pressure equal to about 2 atmospheres, at 50°. By passing sulphurous acid gas through fused chloride of calcium, into a flask cooled to a very low temperature, from surrounding it with a mixture of ice and salt, M. Bussy has succeeded in obtaining a transparent colourless liquid, which he considers as pure sulphurous acid. Its specific gravity was 1.45. At 0° Fahrenheit, it was liquid, and very volatile. At 14°, it boiled rapidly, and produced shortly such a degree of cold as, for a time, to stop its further evaporation.

A thermometer, covered with a bit of loose cotton, and dipped into the fluid, on holding it in the air, sunk from 50° to — 70°. In a vacuum it cooled to — 90°. Not only was mercury frozen by it, but spirit of wine, whose specific gravity was 0.852, at 55°. Chlorine and ammonia were reduced to liquids, and cyanogen was crystallized in the cold thus produced.

Its specific gravity in the state of a gas, at 60°, must be

2.22. 100 cubic inches, weighing 67.77 grains. Its constituents are sulphur 1 atom 16, oxygen 2 atoms 16 = 32, no condensation being produced. It has a pungent, suffocating, stinking smell. It extinguishes flame, and is fatal to animal life. It reddens, and then destroys many animal and vegetable colours, and bleaches or whitens silk. It is the ready production of this acid that produces the smell usually imputed to sulphur.

Water dissolves about 32 volumes of this gas, and the solution has a specific gravity of 1.05, and a sulphurous astringent taste. Sulphuric acid is produced by confining atmospheric air, or oxygen over this liquid; but dry sulphurous acid gas and oxygen do not act upon each other.

This gas is not decomposed by a red heat, but when mixed with hydrogen, and passed through an ignited tube, the sulphur is precipitated, and water formed. It is decomposed by red-hot charcoal also.

When a mixture of sulphurous acid gas, and chlorine, is made over water, a part of the water is decomposed; the sulphurous acid attracting the oxygen, produces sulphuric acid, the chlorine attracting the hydrogen, forms muriatic acid. The saline compounds it produces with the various metallic bases, are called sulphites. When kept in the air, they gradually absorb oxygen, and become sulphates.

Sulphite of ammonia is sometimes used in chemical analysis.

§ 3. *Sulphuric Acid* is prepared in large quantities by various manipulations, for supplying the extensive demand of various arts and uses.

Large chambers are built, some of which are one hundred and twenty feet long, forty wide, and twenty high, forming a space of ninety-six thousand cubic feet. These are lined throughout with lead, and furnished with doors, which are made to shut air-tight, and the bottom covered with water. A number of stands are placed at regular dis-

tances in the room, to hold small plates of lead, above the surface of the wafer. A dry mixture is made of 8 parts of Sicilian sulphur, and 1 of rough nitre. This is distributed upon the stands, in the proportion of about 1 lb. to every 300 cubic feet, nearly of the space. When the charges are arranged, they are fired by a red-hot iron, and the doors quickly closed. A rapid combustion commences, and lasts thirty or forty minutes. About three hours are allowed for the condensation of the vapour, and then the doors are thrown open for about twenty or thirty minutes, to fill the room with fresh atmospheric air, during which, the plates are again charged, and preparations made for a fresh combustion.

This operation is repeated every four hours, night and day, until the water is sufficiently acidified, or has obtained a specific gravity of 1.350 to 1.560, when it is drawn, first into leaden, then into glass, or platinum vessels, in which, successively, the superfluous water is evaporated.

When sulphur is burnt in oxygen it forms sulphurous, not sulphuric acid. When burnt as above described with nitre, sulphuric acid is formed, and yet the nitre is not adequate to the supply of $\frac{1}{10}$ part of the oxygen required. This process is not so simple therefore as would at first appear.

During the combustion, the nitric acid of the salt is decomposed, and converted into nitric oxide gas, and oxygen. This oxygen combines with the sulphur, and forms sulphurous acid. The nitric oxide gas instantly attracts oxygen from the inclosed atmosphere, and becomes nitrous acid. The nitrous and sulphurous acids combine with the moisture of the atmosphere, and form a crystalline compound which is instantly precipitated into the water below, and decomposed. Sulphuric acid is formed, and nitric oxide again produced. This nitric oxide again combines with a portion of the oxygen of the atmosphere, and forms nitrous acid; this again combines with a portion of sulphurous acid,

and delivers up its oxygen as before. Thus the nitric oxide becomes a carrier. It draws oxygen from the surrounding air, and delivers it up to the sulphurous acid, until the whole is converted into sulphuric acid.

Sulphuric acid is also obtained, by distilling at a high temperature sulphate of iron, previously deprived of its water of crystallization. When the acid is obtained in this way, it sometimes emits very dense fumes, and frequently a part of it concretes into a white tough crystalline mass. This concrete mass may be distilled over at a temperature of between 104° and 122°. The fluid remaining in the retort then ceases to boil. This production becomes concrete at 66; it appears to be pure sulphuric acid, free from water. Its specific gravity is about 1.97. It is highly refractive. When exposed to the air, part of it evaporates, and the remainder, by absorbing moisture, becomes common sulphuric acid.

This anhydrous acid, in combining with pure baryta, produces incandescence. (See Journal de Pharmacie, No. X.) Pure sulphuric acid is composed of 1 atom of sulphur 16, + 3 atoms of oxygen 24; = 40. The most concentrated sulphuric acid of commerce, or hydrated sulphuric acid, usually contains 1 atom of pure acid 40, and 1 atom of water, 9; = 49. Its specific gravity is nearly 1.8485. But the sulphuric acid of commerce generally contains 4 or 5 parts of sulphates of potassa and lead, sometimes more, and its specific gravity is 1.5. Therefore to obtain the hydrated sulphuric acid pure, the chemist is obliged to re-distil it. This may be done in a platinum, or coated glass retort, containing a few pieces of platina foil, over a charcoal stove. It is a colourless fluid; its cohesive attraction is nearly equal to that of oil of almonds. It freezes at about 15°. It distils at a little above 600°. The capacity of its vapour for caloric is small, and, in consequence, it requires a regulated heat for its distillation.

When sulphuric acid is mixed with water, caloric is evolved. If four parts of concentrated hydrated-sulphuric acid be mixed with one of water, the temperature will be raised from 50° to 300°. A diminution of bulk follows.

It is, as is well known, extremely acrid and caustic. It decomposes animal and vegetable bodies, attracts their hydrogen and oxygen in the state of water, and by separating and retaining a portion of the charcoal, it blackens them and acquires a dark colour. It absorbs hygrometric water very powerfully. The strength of it may be computed from its specific gravity; and chemists have formed tables for that purpose. But to render them worthy of dependence the purity of the acid should be ascertained. This is best and most commonly done by evaporating a known weight of the acid, and weighing the residuum. The following table, abstracted from Dr. Ure, shows the quantity of liquid and of dry sulphuric acid in 100 parts of dilute acids of different densities.

Specific Gravity.	Liquid Acid.	Dry Acid.
1.8485	100	81.54
1.8376	95	77.46
1.8115	90	73.39
1.7673	85	69.31
1.7120	80	65.23
1.6520	75	61.15
1.5975	70	57.08
1.5390	65	53.00
1.4860	60	48.92
1.4360	55	44.85
1.3884	50	40.77
1.3440	45	36.69
1.2999	40	32.61
1.2572	35	28.54
1.2184	30	24.46

Specific Gravity.	Liquid Acid.	Dry Acid.
1.1792	25	20.38
1.1410	20	16.31
1.1019	15	12.23
1.0682	10	8.15
1.0336	5	4.08
1.0074	1	0.8154

Sulphuric acid is decomposed by heat, simply in passing it through a platinum tube strongly ignited. Sulphurous acid, oxygen and water are produced. Heated with charcoal, carbonic and sulphurous acids are produced. Hydrogen at a high temperature attracts oxygen from it and converts it to sulphurous acid. Sulphur boiled with it does the same. It is decomposed by many of the metals, and combines with the oxides of almost all of them.

This acid is used very extensively in various arts, in bleaching, dying, &c. and in the chemist's laboratory.

§ 4. *Sulphate of Ammonia.* This salt is readily formed by decomposing 100 parts of the common sesquicarbonate of ammonia by 88 of sulphuric acid diluted. The salt crystallizes in flat six-sided prisms. It consists of 1 atom sulphuric acid, 40 + 1 ammonia, 17; = 57, to which add 2 atoms of water 18, = 75 it has a bitter sharp taste. When heated it melts, partly sublimes with an excess of acid, forming a bisulphate while ammonia is evolved. It is soluble in 2 parts of water at 60°.

§ 5. *Hyposulphurous Acid* was first noticed by M. Gay-Lussac, and first obtained in an uncombined state by Mr. Herschell, by mixing with hyposulphite of strontia, obtained by exposing a solution of the sulphuret to the air, and afterwards filtering it, a quantity of dilute sulphuric acid. When filtered it was clear; but on standing, it became milky, depositing sulphur. A slight heat or exposure to air decomposed it. It produces

colourless crystals with lime and strontia, it combines with the alkalies also, and other bases. It appears to consist of sulphur 1 atom 16, and oxygen 1 atom 8 = 24.

When iron filings are slowly dissolved in sulphurous acid, they partly decompose it, attracting the necessary proportion of oxygen from the acid, and converting it into hyposulphurous acid, with this they combine, producing hyposulphite of iron.

This acid has a peculiar tendency to form double compounds with the alkalies and silver. When hyposulphite of soda is poured upon oxide of silver, a part of the soda is separated, and a hyposulphite of soda and silver produced. These double salts are all of them remarkable for an excessively pure intense sweetness of taste. The hyposulphite of ammonia and silver is so powerful in this respect, that one grain communicates a sensible sweetness to two quarts of water.

Hyposulphites of the alkalies may be obtained by passing a current of sulphurous acid through a solution of the respective alkalies or alkaline earths, and sulphur. By adding the hyposulphites in solution to muriate of silver, the muriate is dissolved, forming a similar sweet solution.

§ 6. *Hyposulphuric Acid.*—Another compound of sulphur and oxygen has been discovered by Messrs. Gay-Lussac and Welther, the composition of which has suggested the name of hyposulphuric acid. It is obtained by a circuitous process. A current of sulphurous acid passed through the black oxide of manganese absorbs from it a portion of oxygen, and forms a hyposulphate of manganese, which must be purified by solution in water. Pure baryta precipitates the manganese, and combines with the acid, forming a soluble salt. Sulphuric acid separates the baryta, and leaves the hyposulphuric acid in solution. This solution is decomposed by heat; but will bear a considerable concentration in an exhausted receiver. It ap-

pears to consist of sulphur 1 atom 16, + oxygen 2½ atoms, 20 = 36.

By heat it is decomposed, sulphuric and sulphurous acids being produced; it produces soluble compounds with baryta, strontia, lead, and silver: indeed, all its saline combinations are soluble, and give out sulphurous acid on being heated.

§ 7. *Chloride of Sulphur.*—Sulphur heated with chlorine absorbs rather more than twice its weight of it; forming a chloride of sulphur, a greenish yellow liquid consisting of 1atom, sulphur 16, + 1 atom chlorine 36; = 52. Its specific gravity is 1.7. It emits acrid suffocating fumes, with a peculiar smell. It is volatile below 200°; mixed with water a decomposition ensues, sulphur is deposited, and the water decomposed; muriatic sulphurous and some sulphuric acid being produced. Alkohol, ether, and ammonia, are decomposed by it also. It dissolves sulphur. Iodine unites with it, and produces a black crystalline compound. It is decomposed at a temperature a little above that at which it is produced.

§ 8. *Iodide of Sulphur.*—It is readily produced by melting the ingredients together in a closed tube. It is a dark radiated body, resembling in appearance the sulphuret of antimony.

§ 9. *Iodo-sulphuric Acid.*—If sulphuric acid be dropped into hot concentrated solution of iodic acid, a yellow fusible body, which crystallizes in rhombs is formed. It appears to be a compound of iodic and sulphuric acids.

§ 10. *Sulphuretted Hydrogen.*—1. This gas may be obtained by acting with dilute sulphuric acid upon sulphuret of iron, or pure hydrosulphuret of potassa; or by the action of muriatic acid upon sulphuret of antimony.

It is a permanently elastic fluid, at the usual temperature

and pressure. By decomposing sulphuret of iron with muriatic acid, in a sealed bent glass tube, and distilling, M. Farraday obtained it in an extremely limpid state, under a pressure that appeared to be about equal to 17 atmospheres at 50° Fahrenheit.

It consists of 1 atom sulphur 16, + 1 hydrogen 1; = 17. Its specific gravity is 1.18. 100 cubic inches weigh 36 grains.

It has a nauseous fetid smell, resembling that of rotten eggs, and an acid taste. Air mixed with $\frac{1}{150}$ of this gas is fatal to respiration. It extinguishes flame, but burns slowly in atmospheric air, producing water, sulphurous acid, and a little sulphur.

Two volumes of it combine with three of oxygen gas, the hydrogen combining with one volume, the sulphur with two. It blackens silver, mercury, acetate of lead, and white lead. One measure of it, mixed in 20,000 of hydrogen, or common air, is said to produce this effect very sensibly on white lead, or oxide of bismuth.

It is decomposed by chlorine and iodine, both of which attract its hydrogen, and precipitate the sulphur. Sulphurous acid and sulphuretted hydrogen, decompose each other, and water is produced.

When pure, three volumes are absorbed by one of water, according to Gay-Lussac. The solution reddens infusion of violets or litmus; when kept, it slowly lets fall the sulphur.

Potassium and sodium heated with it decompose it, becoming luminous, and a sulphuret is produced, the hydrogen being evolved in the same proportion as from water. It combines with the alkalies, earthy bases, and metallic oxides, producing hydrosulphurets, which are soluble in water, acrid, bitter, have the smell of rotten eggs, and are decomposed by heat, and almost all acids. This gas, or a

solution of it, precipitates all metallic solutions, except iron, nickel, cobalt, manganese, titanium, and molybdenum.

2. *Hydrosulphuret of ammonia.*—Hydrosulphuret of ammonia is produced by uniting equal volumes of sulphuretted hydrogen and of ammonia, which combine and produce crystals. It is constituted of sulphuretted hydrogen 2 atoms, 34 + ammonia 1 atom 17; = 51. When quite pure and fresh, the crystals are white and transparent, but soon become yellow on exposure to the air, and are very volatile. It is frequently used as a test of lead.

3. *Hydrosulphurous Acid.*—Sulphuretted hydrogen and sulphurous acid, if moisture be present, decompose each other; water is formed by the union of the oxygen of the latter gas with the hydrogen of the former, and the sulphur of each is deposited. But if three volumes of sulphuretted hydrogen, and two of sulphurous acid, both well dried, be mixed, they combine into a solid of an orange yellow colour. This Dr. Thompson calls hydrosulphurous acid. It is hot and acid to the taste. While dry, it does not affect the colour of litmus; on the addition of water, litmus is reddened by it. Heat easily decomposes it.

4. *Sulphochyazic Acid.*—A yellow crystallized compound may be formed, it appears from the experiments of M. M. Gay-Lussac and Porret, by the action of sulphuretted hydrogen and cyanogen upon each other.

Mr. Porret obtained a compound, which he called sulphochyazic acid, by the action of sulphuret of potassa on Prussian blue. When pure, it is a colourless transparent liquid, with a pungent smell, not unlike acetic acid. It precipitates the salts of silver white, and combines with other metallic oxides. It appears to be composed of

Sulphur	2 atoms		Sulphur 2 atoms
Carbon	2 atoms	or of	
Nitrogen	1 atom		Hydrocyanic acid 1 atom.
Hydrogen	1 atom		

§ 11. *Bisulphuretted hydrogen.*—1. Bisulphuretted hydrogen is produced when solution of hydrogenated sulphuret of potash, formed by boiling flowers of sulphur in solution of caustic potassa, is poured gradually into liquid muriatic acid. It falls to the bottom of the vessel assuming the appearance of an oil. It appears to be constituted of sulphur 2 atoms 32, and hydrogen 1 atom 1; = 33. It is heavier than water; in smell it resembles sulphuretted hydrogen. It is inflammable, and while burning, diffuses the smell of sulphurous acid. It is decomposed by a gentle heat.

It combines with earths and alkalies, forming hydrogenated sulphurets, compounds of a deep greenish yellow colour; bitter, acrid, and offensive, which gradually part with their sulphur, even when kept in close vessels, and which rapidly attract oxygen from the air. They are decomposed by sulphuric, muriatic, and certain other acids; sulphur is precipitated and sulphuretted hydrogen evolved. They produce hydrosulphurets, on boiling them with silver or copper filings.

Sulphur and hydrogen appear to combine in other proportions, but they have not as yet been clearly elucidated.

2. Hydrogenated sulphuret of ammonia is obtained, by putting into a retort 6 parts of muriate of ammonia, 2 parts of lime, and 1 part of sulphur, intimately mixed, applying a receiver, which must be kept cool; the retort may be slowly heated, and the heat increased almost to ignition. It is of a deep yellow colour, and smells of both the gasses. When concentrated, it emits dense white fumes, and was formerly called Boyle's fuming liquor. If kept in vessels

made of glass, containing lead, it blackens them. It will dissolve its own weight of sulphur.

Sulphur and nitrogen do not appear capable of forming any definite compound; and yet the nitrogen evolved during the decomposition of some animal matters, appears to be impregnated with it.

§ 12. *Sulphuret of Carbon* is obtained by passing the vapour of sulphur through a red-hot tube, containing pure carbon. The gas and vapour that are produced must be received into water. The vapour thus condensed, may be rectified by re-distilling it at a heat not exceeding 110°. It appears to consist of sulphur 2 atoms 32, + carbon 1 6°; = 38. It is a colourless transparent fluid, of a peculiar fetid smell, and an acrid taste. Its refractive power is 1.65. It is not soluble in water. It is extremely volatile, and produces intense cold during its evaporation. A thermometer, covered with a bit of lint and dipped into this compound, on being placed in an air-pump vacuum, rapidly sunk to — 80 Fahrenheit. It is inflammable at 650°, and burns with a blue flame.

Sulphuret of carbon and ammonia decompose each other. When from 15 to 17 measures of sulphuret of carbon, 100 of alkohol, saturated with ammonia, and 45 of alkohol, are put into a wide-mouthed flask, of such a size as to be nearly filled with the mixture, closed with a glass stopper, and kept in a temperature of from 54° to 57°, in about ten minutes the mixture becomes of a yellow colour, and brown in about twenty. In a short time numerous plumose crystals form at the bottom of the flask, and a similar substance is seen adhering to the upper part of the vessel. For above an hour these crystals continue increasing. Another set of crystals then begin to appear, which proceed more slowly, and group more distinctly. They are prismatic, different in colour, more brilliant, more perfect in form, and sometimes half an inch in length. While these

crystals are forming, the former decrease in quantity, and sometimes wholly disappear.

The former of these compounds, M. Ziez[illegible]nn. de Chimie, xxvi.) calls hydrocarbosulphuret of ammonia. On decanting the liquid, a light yellow deliquescent salt is obtained, which rapidly absorbs the hygrometric moisture of the air, and becomes red. It is soluble in water, sparingly so in alkohol, and decomposes readily, even by the action of the air.

The latter of these compounds he names hydrosulphuretted-hydrosulphocyanate of ammonia. When the alkohol is decanted from the crystals, they may be dried quickly by folds of blotting paper, and then in an exhausted air-pump receiver. It becomes partially decomposed by the air, is deliquescent, and from a neutral salt becomes slightly alkaline. It readily dissolves in water, sparingly in cold alkohol, and the solutions do not decompose spontaneously when confined from the air. Various salts decompose it by double attraction, and it is possible that the pure acid may be obtained by sulphuric or muriatic acid attracting its base.

Sulphuret of carbon dissolves phosphorus, producing a very inflammable compound.

Article 6. Of Phosphorus.

§ 1. *Of the Properties of Phosphorus.*—Phosphorus is a chemical element, which is found mineralized chiefly in apatite, a native phosphate of lime, that is met with among the primitive rocks in different parts of the earth. It occurs also, combined with iron and lead; it is met with combined, in vegetables, and it exists abundantly in the bones, urine, and other parts of animals.

The chemist obtains it by the decomposition of certain parts of animal bodies. Its strong attraction for oxygen,

even at a low temperature, with the evolution of a large quantity of caloric and light, during combination, attracted great attention to it, and has caused it to be considered as the most inflammable of the simple chemical elements.

It is mostly obtained from calcined animal bones, a phosphate of lime. Upon twenty parts of this powdered bone, pour forty of boiling water, and sixteen and a half of strong sulphuric acid; after maceration and frequent stirring during twenty-four hours, strain off the clear liquor, and evaporate to half its bulk. When cool, decant, and again boil the liquor to dryness. The white matter thus obtained, is phosphoric acid, containing from eight to twelve per cent. of phosphate of lime. Powder this, and mix it with half its weight of charcoal; pour the mixture into a coated earthen retort, and distil off the phosphorus at a red heat, keeping the nose of the retort immersed in water. A large quantity of gas escapes during the operation, which inflames as it comes into the air. The phosphorus is then to be purified by straining it under warm water through wash-leather. It is scarcely necessary to say, this process is dangerous to those unaccustomed to chemical manipulations. Phosphorus is semi-transparent, flexible, and waxy, when pure and fresh made; if quite pure, it is white, but usually it has a reddish tint. ' Its chemical equivalent is nearly 12: its specific gravity is 1.77. It melts at 105°. If heated to 150°, and suddenly cooled, it becomes dark coloured. If cooled slowly, it remains transparent. At 550, excluded from the air, it distils over unchanged. It is tasteless, insoluble, and if swallowed very poisonous.

Exposed to the air at about 60° or 70°, slightly opaque fumes are exhaled, which, in the dark, are luminous. They are accompanied with a peculiar garlick-like smell. Exposed in air, which is freed from oxygen, it is not at all luminous. When exposed in the atmosphere to the tempe-

rature of about 148°, it inflames, and then burns with an excessively brilliant light and intense heat, producing a suffocating smell, and a dense white smoke, which is phosphoric acid. It will burn in an atmosphere, rarefied above sixty times. It burns with a brilliant light in nitrous oxide, also in chlorine.

When exposed by Sir H. Davy to 500 plates of the voltaic circle at the Royal Institution, about four times its volume of gas was evolved, which proved to be phosphuretted hydrogen; and the phosphorus became of a deep red brown. It is highly probable that the hydrogen in phosphorus, as well as in sulphur and carbon, is an impurity which cannot be wholly separated on account of the powerfully increasing attraction, which operates here as in some other instances, for the last minute portions of the elements: thus also, muriate of lime holds the last portions of water with a force which a red heat does not overcome.

It is usual to keep phosphorus under water; the surface of it becomes covered with a thin whitish crust, which has not been accurately examined. It appears to be an oxide perhaps hydrated.

When phosphorus which is burning in a confined portion of atmospheric air, is extinguished by the combination of all the oxygen that it contained; the unburnt phosphorus becomes of a reddish colour and less fusible than before, and inflames on coming into the air. This is considered to be an oxide of phosphorus.

§ 2. *Hypophosphorous Acid.*—Hypophosphorous acid is obtained by pouring upon one part of phosphuret of barium four parts of water; phosphuretted hydrogen forms. When it has escaped, [redacted] the mixture upon a filter to separate the insoluble [redacted]phate of baryta which has formed. To the clear liquid, which is a hypophosphite of baryta, add sulphuric acid until sulphate of baryta no longer falls down. The clear solution of hypophosphorous acid may be slowly

evaporated, when it becomes viscid, acid, incapable of crystallizing, and has a strong attraction for oxygen. It appears to consist of 2 atoms phosphorus 24, + 1 of oxygen 8 = 32. It forms definite compounds with earthy and alkaline bases, which are extremely soluble, difficult to crystallize, and deliquescent.

§ 3. *Phosphorus Acid* is obtained by mixing protochloride of phosphorus and water. A decomposition of a part of the water takes place, and muriatic and phosphorus acids are produced. By evaporation, the former acid and a part of the water escape, the phosphorus acid is reduced to the consistence of a syrup, and becomes a white crystalline solid mass on cooling. It appears to consist of 1 atom phosphorus 12, + 1 atom of oxygen 8; = 20. It has a disagreeable fetid smell, a sour taste, is very soluble, reddens vegetable blues, and emits penetrating white vapours on being heated; and on raising the heat it inflames. It combines with alkaline and earthy bases.

§ 4. *Phosphoric Acid.*—It occurs native, combined with lime, in abundance in Spain and other places; but it is usually obtained from bones, as was directed in the preparation of phosphorus. If wanted very pure, it is most readily obtained so, by heating phosphate of ammonia to a red heat in a silver or platinum vessel. It is composed of 1 atom of phosphorus 12, + 2 of oxygen 16; = 28. Its specific gravity is 2.68. It is a transparent vitreous body, deliquescent, soluble, and in its usual state containing, according to Berthier, 20 to 25 per cent of water. It is inodorous, and very sour.

A dry phosphoric acid, perfectly free from water, may be obtained by burning phosphorus in oxygen at a high temperature. It is flocculent, and excites great heat on the addition of water, which it attracts with great energy.

This dry acid is volatile at a bright red heat, but loses its volatility on the addition of a little water.

It forms numerous neutral and acid saline compounds with the alkalies and earths, &c.

Phosphate of ammonia is usually obtained by saturating the phosphoric acid produced from bone earth, with carbonate of ammonia, decanting, evaporating to dryness, re-dissolving and crystallizing. It forms octoedral crystals of a bitter taste, and soluble in twice their weight of water.

§ 5. *Phosphatic Acid.*—When phosphorus is exposed in sticks upon a funnel in damp atmospheric air, and kept at a low temperature, a slow combustion goes on. The compound formed will slowly drop through the funnel into a vial.

It may be concentrated in an exhausted receiver by the help of sulphuric acid, to a viscid, colourless, liquid; which smells slightly of phosphorus, has an acid taste, and reddens litmus. When heated it exhales phosphuretted hydrogen, and phosphoric acid remains. According to M. Thenard, this acid, which is called phosphatic, is constituted of phosphorus 3 atoms, oxygen 5 atoms.

§ 6. *Protochloride of Phosphorus.*—Phosphorus unites with chlorine in two proportions. The protochloride may be obtained by the distillation of a mixture of phosphorus and corrosive sublimate—a perchloride of mercury.—The latter is changed into a protochloride of mercury or calomel, and the chlorine thus separated is attracted by the phosphorus. This compound consists of 1 atom phosphorus 12, + 1 chlorine 36; = 48. Its specific gravity is 1.45.

It is a clear limpid liquid. While pure it does not affect the colour of vegetable blues, but when mixed with water a mutual decomposition takes place, as was noticed under the preparation of phosphorus acid. It exhales fumes which become acid by acting on the vapour in the air.

§ 7. *Perchloride of Phosphorus* is obtained, by placing phosphorus in contact with chlorine gas. It instantly inflames, burns with a pale yellow light, and the product is a pure white powder which adheres to the vessel. It consists of 2 atoms chlorine 72, + 1 atom phosphorus 12; = 34. It is fusible, and evaporates at about 200. When fused under pressure it crystallizes. Mixed with water, a mutual and violent decomposition follows; muriatic and phosphoric acids are produced. It is decomposed by oxygen at a red heat and inflames.

With ammonia it combines and forms a compound, which has the singular properties of being insoluble in water, fixed at a white heat, and not affected by acids nor alkaline solutions.

§ 8. *Iodides of Phosphorus.*—Phosphorus combines with iodine in two proportions, evolving heat, and sometimes light.

Iodide of Phosphorus is of a reddish brown colour, solid, and decomposes water with great energy. It is supposed to consist of iodine 1 atom 125, phosphorus 1 atom 12; = 137.

Periodide of Phosphorus is a black compound formed by heating one part of phosphorus with rather more than twenty of iodine. It is supposed to consist of 2 atoms iodine 250, + 1 of phosphorus 12; = 262. It does not decompose water.

§ 9. Phosphorus combines with hydrogen forming two different compounds.

Phosphuretted Hydrogen is procured by distilling phosphuret of lime in a retort filled with dilute muriatic acid, or by heating phosphorus in a strong solution of potassa; the extremity of the retort being kept under water, over which the gas may be received. Some water is decomposed in this operation, and phosphoric acid formed. It appears to

consist of phosphorus 1 atom 12, + hydrogen 1 atom 1; = 13. In this compound the hydrogen is not condensed in volume. 100 cubic inches weigh 27.5 grains. Its specific gravity is 0.9. It is a nauseous colourless gas; it inflames on coming into the atmosphere; a dense horizontal circle of white smoke arising, and spreading as it ascends. It dissolves in fifty times its volume of water. In oxygen gas it burns with great brilliancy. With a volume and a half of oxygen it produces phosphoric acid, with one volume, phosphorus acid. It burns in chlorine with a pale blue flame. Mixed with nitrous oxide, the gasses decompose each other. The same happens with nitric oxide, and sulphurous acid. It lets fall a portion of phosphorus on standing, and, at the same time, loses its property of spontaneous inflammation; and probably forms a subphosphuret. It is decomposed by electricity also.

Subphosphuretted Hydrogen is obtained by heating solid hydrated phosphorus acid in a small retort which it scarcely fills. It is converted into phosphoric acid; and a colourless gas, smelling less nauseous than the last, comes over in quantity. It appears to consist of phosphorus 1 atom 12, + hydrogen 2 atoms 2; = 14. There is no condensation of volume. Its specific gravity is 0.97. 100 cubic inches weigh 29.5 grains, 1 volume is absorbed by 8 of water. It does not inflame spontaneously. It detonates with oxygen at about 300°. Potassium decomposes it, forming a phosphuret, and liberating the hydrogen. Sulphur decomposes it in the same manner.

Phosphorus appears to be capable of suspension in small quantity in nitrogen, but no definite compound of these is known.

§ 10. *Phosphuret of Carbon* is obtained as follows. Let phosphuret of lime remain in water, until the evolution of gas has ceased; add muriatic acid in excess, agitate the

mixture a little, and filter it. The phosphuret of carbon remains on the filter. It appears to consist of 1 atom of carbon 6, + 1 atom of phosphorus 12; = 18. It is a yellowish powder, insipid, inodorous, and slowly deliquescent. It burns at a red heat.

§ 11. *Phosphuret of Sulphur.*—The ingredients of this compound *appear* readily to unite in any proportion. In equal proportions the mixture is of a reddish colour, and sulphuretted and phosphuretted hydrogen are evolved during the combination. It is fluid at the usual atmospheric temperature. Two parts of phosphorus and three of sulphur, when mixed, take fire readily upon a slight friction. A mixture of these bodies was one of the contrivances for phosphoric fire-boxes.

Phosphorus is soluble in expressed and volatile oils. When these solutions are rubbed over surfaces exposed to the atmosphere, they become luminous in the dark.

Article 7. Boron.

§ 1.—This chemical element occurs in combination with oxygen, in the state of boracic acid, and in considerable abundance in Italy and some other places. In the combination called borax, it occurs in America, in Thibet, and in some other parts of Asia and Europe.

Borax and boracic acid have been known for some time, and the former has long been in extensive use as a flux. But the base was not discovered until since the application of voltaic electricity as an instrument of chemical analysis. It may be obtained, according to Mr. Berzelius, by fusing potassium with fluo-borate of potassa; or by mixing one part of fused boracic acid with two of potassium, and heating them to redness in a copper tube. At a temperature a little above 300° Fahrenheit, according to M. M. Gay-

Lussac and Thenard, the mixture suddenly ignites, and combination is produced. The contents of the tube are now boron and potassa. When washed with water, the boron is left. It is an olive-brown powder, insoluble in water, and unchanged in the atmosphere.

Heated in a close vessel it becomes more dense, but undergoes no other change. It sinks in sulphuric acid.

Its equivalent number is estimated at 6. It is insipid, and does not affect vegetable colours. It is a nonconductor of electricity.

At the temperature of about 600°, it takes fire, and burns in the atmosphere with great brilliancy, and in oxygen gas with still greater. The compound thus formed is boracic acid.

Boron combines with oxygen with a strong chemical force, and as far as is known, in one proportion only, producing, as has been said, boracic acid.

§ 2. *Boracic Acid* has lately been discovered in great abundance in Italy. It may be purified by distillation with water; or,

It may be obtained by decomposing a solution of borax with half its weight of sulphuric acid. The boracic acid separates, as the mixture cools, in crystals, which may be washed in pure water, and further purified, if necessary, by gentle distillation with water.

The dry acid appears to consist of 1 atom of boron 6, 2 of oxygen 16; = 22; but chemists do not agree as to the atom of boron. Its specific gravity is 1.48 nearly. It is in thin white shining scales, is inodorous, and has a slightly cooling bitterish taste.

When heated, it melts and loses its water of crystallization, which is said to amount to 44.5 parts in 100 of the crystals. If, before it fuses, the heat be suddenly raised, the acid rises with the water; but if the water has escaped

first, it melts into a glass, which is no longer volatile. The specific gravity is then 1.8. It is soluble in fifty times its weight of boiling water. The solution reddens vegetable blues, and decomposes alkaline carbonates. It reddens turmeric, as alkalies do. It is soluble in alkohol: the solution burns with a green flame. It produces various saline compounds, with bases.

Boracic acid readily forms a vitrous compound with earthy bodies, and is useful for glazing or vitrifying the surface of earthen retorts, and thus stopping their pores.

Borate of ammonia is in crystals, consisting of 37.95 acid, 30.32 ammonia, 31.73 water, in 100 parts, according to analysis of Berzelius.

Boron is said to burn with splendour in chlorine. According to M. Berzelius, chloride of boron is a gas, that is decomposed by hygrometric moisture, and a dense vapour produced, which appears to be muriatic and boracic acids. It condenses with a volume and a half of ammonia. Its combination with iodine has not been examined.

Article 8. Selenium.

§ 1. This substance was first observed by M. Berzelius in very small proportion, in the sulphuret of iron obtained at Fahlun, in Sweden; and has since been found mineralized with silver and copper, in a supposed ore of tellurium. It has been found also in the volcanic productions of the Lipari islands, and in Hungary; and lately (as appears by the Annals of Philosophy for January,) in sulphuric acid, prepared from pyrites obtained from the Paris mountain in Anglesea. It appears to be a primary chemical element.

When purified, if it has been cooled rapidly after fusion, its surface is of a deep brown colour, with metallic bril-

liancy; and its fracture is lead coloured, vitreous, and conchoidal. If cooled very slowly, the surface is of a lead colour, without polish and uneven, with a fracture, which is granulated and dull. It is brittle and easily cut. Its specific gravity is 4.3.

It separates spontaneously from the hydroseleniuret of ammonia in cubic crystals.

In very thin laminæ, it is transparent and ruby red. When powdered, it is of a deep red colour, and adhesive.

It fuses at a little above 212°. As it cools, it remains soft for a time, and may be kneaded between the fingers, or drawn into threads, which are elastic, have a perfect metallic brilliancy, are deep red when viewed by transmitted light, and grey by reflected.

It sublimes at a heat below redness, producing a deep yellow gas; it condenses in black drops like mercury. It sublimes in the air unaltered. If touched by flame, it is tinged of a beautiful pure azure blue, and a vapour, having a strong smell, like putrid cabbage, is exhaled.

Heated in oxygen gas, under pressure, it takes fire and burns with a feeble flame, producing the oxide.

It is a bad conductor of heat; a non-conductor of electricity, and a non-electric.

An oxide of selenium appears to be formed by heating selenium in a confined portion of common air. Its chief distinguishing property is a peculiar smell. At a high temperature, it burns in oxygen with a feeble flame.

§ *Selenic Acid* is produced by dissolving selenium in nitric acid, and evaporating the solution, the excess of acid escapes. Upon raising the heat, the selenic acid sublimes, and forms four-sided needle-like crystals, which, while fresh, have a peculiar lustre, but on exposure to the air become dull and adhesive. It is supposed to consist of se-

lenium 1 atom 40, + oxygen 2 atoms 16; = 56. It unites with various bases, forming salts named seleniates.

§ 3. Selenium combines also with hydrogen, and produces a gas, which, like sulphuretted hydrogen, has some acid properties. It appears to consist of selenium 1 atom 40, + hydrogen 1 atom 1; = 41. This gas irritates the mucous membrane, lining the nose, trachea, and lungs to a most violent degree. At first, M. Berzelius says, that an odour, resembling that of sulphuretted hydrogen is perceived; it is soon followed by catarrhal symptoms, heat, pricking, pain in the nose, eyes, and chest, with redness of the eyes. A dry painful cough follows. A small bubble of the gas, the volume of a pea, so destroyed for a time the sense of smell, that a strong solution of caustic ammonia did not affect it.

Moistened paper, wood, or caoutchout gum, receives from this gas a fine red stain, which penetrates to some depth.

It combines, as an acid, with those bases which have a stronger attraction for oxygen than hydrogen has; with other bases it forms seleniurets.

When a polished plate of zinc or iron is immersed in a solution of selenic acid in muriatic acid, it becomes of a copper colour, and reddish brown flocculi are precipitated.

Article 9. Of Fluorine.

§ 1. There is a crystalline mineral frequently met with in England, and other parts of Europe, more particularly in Derbyshire, and from its crystalline appearance called Derbyshire spar, which is a compound of calcium or of lime, and a body which is obtained from it in the state of a peculiar acid.

This acid is strongly suspected to be a compound, containing oxygen or hydrogen; but its base has hitherto resisted every attempt to separate it.

To obtain it, a quantity of fluor spar is to be powdered, and mixed with an equal weight of concentrated sulphuric acid. The fluoric acid is set at liberty, and may be separated by distillation; but, as it has a powerful action upon glass, this must be done in a retort of lead or silver, furnished with a receiver of the same metal. A gentle heat must be applied to the retort, and the receiver kept cool, by surrounding it with ice.

This acid acts with intense activity upon animal and vegetable compounds. If it touch the skin of the operator, it produces a sore, which is painful, ulcerating, and soon becomes deep and extensive.

On a superficial view, it resembles the fuming sulphurous acid; but its specific gravity is much less, being nearly 1.061. It is volatile; it emits white fumes on exposure to the air. It becomes gaseous at 80°. It has not been frozen. On potassium it acts with great energy, producing hydrogen and a neutral salt. With water it produces a hissing noise, and a great heat. A certain small proportion of water increases its density to 1.25; with a large quantity it tastes agreeably acid. It corrodes and dissolves glass with great facility.

It was exposed by Sir H. Davy, with great attention and address, to the action of a powerful galvanic battery, with platinum wires; but no complete decomposition could be produced. The positive wire became rapidly corroded, and was covered with a brown powder; while a small quantity of gas, which appeared to be hydrogen, was evolved from the negative pole. The brown powder might be a compound of the supposed fluorine and platinum; or it might be a compound of fluoric acid and platinum; or, again, it might be a compound of fluoric acid and oxide of platinum. The concentrated sulphuric acid is, as we have shewn, a hydrate. When it decomposes fluate of lime, the fluoric acid may carry the water with it, and this water,

when decomposed, may supply the oxygen to the positive platinum wire, and also the hydrogen which appears at the negative pole.

Its peculiar properties have attracted the attention of different chemists, in particular of M. Berzelius, who is at this time carrying on an extensive series of experiments on it, which have been partly published.

Its atom appears to be between 10.5 or 11.5. It has, in consequence, a remarkably strong saturating capacity; so that the lime contained in 100 parts of fluate of lime, when combined with sulphuric acid, produces 175 parts of sulphate of lime; or 100 parts of fluate of lime consist of fluoric acid 27.3225, lime 72.6775. According to the same chemist, the artificial and the natural fluate of soda and alumina consists of fluoric acid 31.35, soda 44.25, alumina 24.4.

It combines with the alkaline, earthy, and metallic bases, producing neutral solutions which, when soluble, have an invariable disposition to produce crystals that are either acid or alkaline, leaving the liquor in the opposite state.

It has a very strong tendency to produce acid salts, with a double proportion of acid; and also neutral salts with double bases, in which the proportion of acid saturated by each base is equal.

Its most distinguishing character, in which it differs from all other acids, is the property of attracting forcibly and combining with silica, with which it forms a gaseous acid compound, that is partially decomposed by the addition of water only, or of any earthy or alkaline base, forming a double salt with it. Thus, what have hitherto been supposed to be fluates of the different bases, are shewn by Berzelius to be fluosilicates.

In consequence of its energetic action upon such minerals as are insoluble in other acids, it is recommended as an agent in chemical analysis.

§ 2. *Fluate of Ammonia* may be procured by mixing one part of muriate of ammonia with 2¼ of fluate of soda, both being dried and powdered. A gentle heat will volatilize the fluate of ammonia quite free from muriatic acid. This salt is permanent in the air, and very soluble.

§ 3. *Fluoboric Acid* is obtained by distilling in a glass retort 12 parts of concentrated sulphuric acid, 1 of vitreous boracic acid, and 2 of fluate of lime. It generally carries a small portion of sulphuric acid along with it. When pure, it has a pungent suffocating smell, has no action upon glass, but acts powerfully on animal and vegetable matter, apparently from its attraction to water. A piece of paper immersed in it is blackened. 100 cubic inches weigh 72.3. Its specific gravity is 2.37. It has a remarkably intense attraction for water: when a bottle of gas is opened under water, this liquid is forced in with great violence: when the gas is allowed to escape into the atmosphere, it instantly attracts the vapour in it, and appears like a dense fume. It attracts the moisture from any other gas with the same avidity, equally becoming cloudy.

Water absorbs about 700 times its volume of it. The solution has a specific gravity of 1.77. It is extremely caustic. It blackens vegetable bodies as powerfully as sulphuric acid does. It combines with different bases.

It appears to be capable of combining with 1, 2, or 3 proportionals of ammonia.

Heated with potassium or sodium, it is decomposed with brilliant flame, the boron separated, and a fluate produced.

It produces an ether with alkohol.

PART 4. *Of the Metallic Chemical Elements, and of their Combinations with the preceding Bodies and with each other.*

SECTION 1. GENERAL REMARKS.

Under the title of metals was formerly included a compa-

ratively small number of bodies, which were distinguished more by their physical properties than by their chemical. The notion entertained of a metal was that of a body of great specific gravity, of a peculiar brightness and lustre, perfectly opaque, with a tenacity and hardness above other bodies; and that to be a perfect metal, it must be malleable and ductile. Those that were not so, were considered as half or semi-metals. Further enquiry showed them to be good conductors of caloric, and of electricity, to be fusible, and subject extensively to chemical combinations.

The gradual progress of chemical discovery has greatly extended the list of metals, and modified the general complex notion of a metal.

Elementary bodies have, from time to time, been discovered and placed in the class of metals, which agreed in having the brilliancy, opacity, and lustre that was considered as peculiar to metals; but differed more or less in their other properties. The introduction of the voltaic battery as an instrument of analysis, introduced to our knowledge several chemical elements which, in consequence of their strong attraction for oxygen, had until then been concealed from our knowledge. Notwithstanding their small specific gravity, and some other singular properties, they, chiefly on account of their brilliancy and opacity, were placed in the class of metals.

The analogy between the chemical properties of some of these, and some other chemical elements that were subsequently discovered, and which from their extreme difficulty of fusion, or from their strong chemical attractions, have not yet been reduced to a pure uncombined state, has induced chemical writers to conclude them to be metals also; and to place them, provisionally, in the same class. So that in fact, under the class of metals, as now extended, various bodies are included which are connected by a gradation of analogies between each other; but some of which are in

reality, as far as is at present known, almost without any one property that was originally considered as essential to a metal.

Under the class of metals are now included all the electropositive primary chemical elements that are known, those only excepted which have been spoken of above. Formerly the great density, the relative weight, or specific gravity of metals was considered as a remarkably distinctive property. But subsequent discoveries have produced metals which are the lightest of known solids; and the difference between the specific gravity of tellurium and sodium may, perhaps, be filled up by some of the supposed metals which have not as yet been reduced to the metallic state.

Some metals are rarely met with, and in small quantity only. Some few having but feeble chemical affections, are met with more generally in a metallic state. Gold, platinum, and palladium, are always found in the metallic state. Iridium, osmium, and rhodium, are always found alloyed with platinum, upon which they appear to attend like so many satellites. Mercury and silver are frequently found metallic, the latter more rarely, on account of its strong attraction for sulphur. Copper and some other metals are occasionally found native, and even iron, but under peculiar circumstances. Others are found in greater or less abundance, some in immense abundance; totally concealed and altered as to their sensible properties, by being combined, mineralized, as it is called, with each other, with oxygen, with sulphur, and sulphuric acid, muriatic and phosphoric acids.

Some of the metals, those that form the bases of the various earths for instance, occur in extensive strata, extending in all directions; others occur chiefly in vertical veins, extending, for the most part, easterly or westerly.

Metals have a peculiar dense opacity and lustre. Gold, which can be reduced to the $\frac{1}{200.000}$ of an inch, or less in thick-

ness, is still bright and opaque. If a leaf of gold be held between the eye and the light, the numerous holes that extend over it shew a green tint upon the edges, which appears to be produced by transmitted light; but the greater part of the surface is opaque. Silver leaf in the same manner, shews holes over its surface, which appear at the edges to transmit a white light.

The polished surfaces of metals reflect the light that falls on them in great perfection, and have, in consequence, a peculiar brilliancy which is known by the term metallic lustre. It is retained by them even when in fusion. The reflecting power of different metals is in different degrees, and in the same metal it increases as the fineness of the polish increases.

The experiments of Professor Leslie, produced the following scale of their relative lustre.

Brass	100
Silver	90
Tinfoil	85
Planished Block Tin . .	80
Steel	70
Lead	60
Tinfoil softened by Mercury	50

Silvered paper scratched with sand paper, lost nine-tenths of its lustre.

They reflect heat in the same proportion perhaps that they reflect light.

In their uncombined state they are, of all bodies, the best conductors of heat. Among themselves they differ in their conducting power, as has been stated in speaking of caloric.

They are the most perfect conductors of electricity also. When the quantity determined to them is not too great, they transmit it imperceptibly and unaffected. But when overcharged with too great a quantity, they become heated;

and as the proportion increases, they fuse and are evaporated. In their power of conducting electricity also, they differ among themselves.

The texture of metals generally is crystalline, mostly octoedral or cubical; but the texture differs in different metals, and admits of great variety, as well in density as in toughness, malleability, ductility, hardness, elasticity, brittleness, &c.

They are fusible but at very different temperatures. Mercury becomes fluid at 72° below the temperature at which water freezes; potassium at a little above the temperature of the atmosphere; platinum, and some others, require the heat of the oxy-hydrogen blow-pipe, and some have not been fused.

In the following table, the metals are arranged in the order of their fusibility.

Mercury fuses at	— 40°
Potassium	+ 150
Sodium	200
Arsenic	360
Tin	450
Lead	600
Zinc	[illegible]
Antimony	800
Silver, Gold, Copper	at a bright red heat
Nickel, Cobalt, Iron	at a brilliant white heat.

Other metals are fused in small quantities only, or even in minute grains, and others cannot be fused by any means in our power.

Some of the metals are volatile, and may readily be distilled unchanged, if confined in close vessels. Thus,

Arsenic distils over at about . . .	360°
Mercury . . . at	660
Zinc . . Tellurium Potassium . . .	below a red heat.

Gold, on the other hand, is not volatile in the strongest heat of our furnaces; but evaporates in the heat of a tolerably strong voltaic battery; and so do a great number of bodies which are not affected by a lower temperature. This leads to the opinion that all bodies are susceptible of being converted into gasses, if the temperature could be elevated to a sufficient extent.

A certain number of the metals have a tough tenacious texture, and, consequently, are malleable, laminable, and ductile. These properties are possessed, in a very different degree by different metals. Gold is so perfectly malleable, and laminable, that 5 grains are beat out to cover a surface of more than 270 inches. In nickel, the malleability is trifling. The following table exhibits some of the metals in the order of their malleability.

Gold	Cadmium	Iron
Silver	Platinum	Nickel
Copper	Lead	Palladium
Tin	Zinc	

Mercury is distinctly malleable, but at so low a temperature, that its comparative rank has not been ascertained.

Potassium and sodium are soft and malleable also.

The remaining metals are more or less brittle.

The metals which are malleable are for the most part ductile also; that is, they admit of being drawn out into wire. Gold is the most ductile as well as the most malleable of them; silver is extremely ductile as well as malleable; iron, which does not admit of extension into very thin

leaves, is extremely ductile, and may be drawn out into a wire as fine as a human hair. The comparative ductility of metals appears in the following order:

Gold	Iron	Tin
Silver	Copper	Lead
Platinum	Cadmium	Mercury
Palladium	Zinc	Nickel

The ductile and malleable metals possess different degrees of tenacity, or power of resisting forces applied to tear their parts asunder. This tenacity has been measured by suspending bars or wires of a known diameter, and fixing gradually increased weights at the lower end; noting the force applied at the time of disruption. Thus a corresponding wire of each of the following metals supported, before it was broken through, the weights annexed.

Iron wire supported	549.
Copper	302.
Platinum	274.
Silver	187.
Gold	150.
Zinc	109.
Tin	34.
Lead	27.

The hardness of metals, or the force with which they resist the knife, is not so great as it is in some minerals; although all of these are inferior to the diamond in hardness. Such as have been measured have been arranged in the following order:

Tungsten	Copper	Antimony
Palladium	Silver	Cobalt
Manganese	Bismuth	Tin
Iron	Gold	Arsenic
Nickel	Zinc	Lead
Platinum		

Several of the metals are highly elastic.

When this property is united to a certain degree of hardness, it renders them sonorous.

When, in addition to hardness, they are endowed with great tenacity and elasticity, they are very fit for mechanical springs.

These properties are found to be much increased by forming certain mixtures or alloys.

By virtue of an affinity of certain of the metals for each other, they may be forced into union by pressure. Thus a plate of gold is fixed upon the surface of an ingot of silver, or a plate of silver upon a bar of copper. This union is so firm as to admit of the two metals being equally extended together, and drawn into wire without any break on the surface.

The chemical agencies of these elements are very general, as may be imagined. Their properties in this respect are remarkably various; generally speaking, there is no clear line of distinction wherein they differ more from the elements already spoken of, than many of them do from each other. It seems here very remarkable, that the Supreme Creator has not divided these elements into orders, classes, and genera; but has impressed upon each, those properties that are best adapted to the offices it is intended for. The variations in properties appear to be steady and uniform, but of a very mixed nature, and varying frequently in opposite gradations. Any two elements that can be compared have analogies more or less strong in some respects, and discrepancies more or less remarkable and extensive in others. They combine more or less generally and energetically with chlorine, oxygen, iodine, sulphur, and phosphorus, with the three first generally producing heat and light, and losing their physical properties, being converted into earthy or saline bodies; and when their compounds are exposed to the voltaic agency, they are attracted to the negative pole of the battery.

All the metals have an attraction for oxygen, and are

capable of producing with it definite compounds; the sensible properties of which are altogether different from those of the respective elements.

As oxygen gas constitutes a large portion of the atmosphere, metallic bodies are constantly exposed to its action, except when particular precautions are taken to prevent it. The chemical affections of oxygen and the metals are, therefore, of great consequence, not to the chemist only, but also in their applications to various mechanical arts, and in domestic life. Some metals have so powerful an attraction for oxygen, that they separate it from all combinations. Potassium, for instance, at a low temperature, instantly decomposes water with great energy, noise, and scintillation, exciting light and heat.

Manganese, arsenic, iron, copper, and even lead, as well as many other metals, are capable of combining with the oxygen of the air, with more or less force. Some require to be assisted by moisture or heat. A great many decompose water; and this takes place more freely as the temperature is elevated.

Metals, in combining with oxygen, produce heat and light; and hence are called combustible or inflammable, although it is unknown how this light and heat are produced. Thus iron, zinc, and arsenic, when heated to a bright red, burn in oxygen with a brilliant light. In the very elevated temperature of the voltaic circle, gold, silver, and platinum burn with flame and scintillation, in the same manner, during their combination with oxygen.

Some metals have a strong attraction for that proportion of oxygen that produces a protoxide, and a weaker attraction for the second proportion. Some, on the contrary, combine more strongly with a larger proportion of oxygen than with a smaller. When peroxide of iron and pure iron are introduced into a solution of sulphuric acid, the peroxide gives up its second portion of oxygen to the iron, and

it is converted into a protoxide. Protoxide of mercury, on the other hand, readily divides itself: one half, upon any occasion, assuming its metallic state, gives up its oxygen, and the other half is converted into a deutoxide.

Many metals are not acted upon by oxygen, or but very slightly, below a certain temperature. Thus, as has been said, gold, silver, and platinum require the heat of a voltaic battery; mercury is not acted on by oxygen below 500°; and by exposure to a red heat, the oxygen is again separated. Lead soon becomes tarnished by atmospheric air; at a certain elevated temperature, it is converted into a protoxide; and at a certain further elevated temperature, into a deutoxide: at a further elevation, part of the oxygen escapes again.

In chemical decompositions, the metals frequently attract oxygen from each other, according to their relative attractive forces. Thus oxide of mercury, mixed with iron filings and heated, will part with its oxygen to the iron. Charcoal, having a stronger attraction for oxygen, at an elevated temperature, will attract it from most of the metals, when heated with them.

Some of these metals have a slight attraction for oxygen, are combined with it by some circuitous process, and part with it with great facility by mere increase of temperature.

In consequence of this slight attraction, gold, silver, and mercury were formerly dignified by the title of noble metals. Gold, platinum, and silver derive their greatest and most useful value from the very slight chemical action that oxygen and most other bodies possess over them.

Water, the presence of which is as general almost as the presence of atmospheric air, is decomposed, under favourable circumstances, by all those metals which have an attraction for oxygen more powerful than hydrogen has. Iron, as well as many other metals, is thus circumstanced.

Iron filings, when wet and confined, decompose the wa-

ter, are converted into an oxide, and the hydrogen is left free. The decomposition is more rapid as the temperature rises. Most of the metals that are capable of attracting oxygen from the atmosphere, at the usual temperature, are capable of decomposing water. Some metals are said to be scarcely, or not at all, acted upon by pure water, or dry air, that are perfectly oxidized by the common atmosphere, which is always moist, and by common water, which always contains air. This is said to be the case with iron.

The decomposition of water is rendered more rapid, if an acid be added, in consequence of the attraction of the acid, not for the metal, but for the oxide. Another consequence of this action of the acid is, that it sometimes modifies and confines the attraction between the metal and oxygen. Thus tin would decompose water, and combine with the oxygen, forming a peroxide, but the acid arrests it, and combines with it in the state of a protoxide. Iron also would pass into the state of a peroxide; the presence of sulphuric acid arrests it, and combines with it in the state of a protoxide.

If a peroxide of iron be added to sulphuric acid, it combines with it. If a portion of metallic iron be now added, it attracts a part of the oxygen from the peroxide, and the whole is converted into a protoxide.

These metallic elements always combine with oxygen in definite proportions. When, as is frequently the case, they are capable of forming two or more oxides, the succeeding oxides are multiples or submultiples of the first or protoxide. Copper, for instance, forms two oxides. In the protoxide, 100 of the metal combines with 12.5 of oxygen: in the second or deutoxide it combines with 25 of oxygen.

The oxides of different metals vary in their respective sensible properties, but the sensible properties of each particular oxide are uniform.

Water has a powerful attraction for a great number of oxides. It combines with them in different proportions, and produces different phenomena.

Many of the oxides combine, with a certain quantity of water, with great energy into a dry solid, evolving a considerable quantity of caloric. In this state, the oxide is called a hydrated oxide. Fresh-burnt limestone, for instance; a combination of calcium and oxygen, if left open to the atmosphere, gradually attracts the hygrometric water, falls into powder, and increases in bulk and weight almost one-third; that is, 28 of pure lime will produce nearly 37 of dry hydrate of lime.

Lime is soluble in water also, forming a perfectly transparent solution, in the proportion of about 1 part in 650 of water at 40°.

If lime-water be evaporated under an exhausted vessel, a third combination is produced, in crystals, in which the water is to the lime as 31 nearly to 100.

Some of these hydrated oxides, on exposure to heat, part with their water again more readily than others. Lime, for instance, is easily reduced to the first hydrate. Then it parts with it more difficultly, and as the water evaporates, the remaining portion of it seems to form successive sub-hydrates. At least, it is retained with an increasing force, and requires a red heat kept up for some hours to separate it wholly.

In baryta, strontia, potash, soda, a part only of the water can be separated by heat. The remainder is retained with such force, that it can be separated only by chemical attraction.

Some metallic oxides, or their hydrates, are extremely soluble in water, others are soluble in certain proportions, and many are altogether insoluble. They are of various colours; and the colour of an oxide, or of its compounds, is often one of its most uniform distinctive marks. The

protoxide of manganese, for instance, is always green; the deutoxide, brown; and the peroxide, black. The protoxide of lead is yellow; the deutoxide, red; the peroxide, brown; the carbonate is always white.

Most of the metals form oxides only by their combination with oxygen. But some of them, in combination with oxygen, produce compounds which have the properties of acids; and, like other acids, that of combining with alkalies and other oxides, forming saline compounds.

Generally, the acidifiable metals produce oxides with a smaller proportion of oxygen, and acids with a larger proportion.

The compounds of the different metals with oxygen or the oxide, combine very extensively with different acids, and thus form numerous classes of saline compounds.

These combinations are attended with several phenomena, which deserve attention.

That combination may take place with facility, it is necessary, as has been said, that the elements, or at least one of them, be presented in a fluid state. This state is sometimes obtained by the application of caloric. But, generally speaking, solution in a fluid menstruum, when practicable, is most convenient. Water is the fluid most ready, and at the same time the most generally applicable to this purpose.

Frequently the water serves no other purpose than that of an unresisting medium and vehicle, in which the respective atoms are free to move. Sometimes its elements are separated by the force of the attraction, and one or both of them become agents; and frequently a part of the water, in its undecomposed state, becomes an element in the resulting compound; appearing to become solidified, as in the constitution of hydrates of baryta, of lime, and of muriate of lime, &c. When the resulting metallic compounds are crystallizable in water, sometimes during their crystalliza-

tion they separate from it. Thus nitre and sulphate of potassa contain no water chemically combined in their crystals.

Other compounds are incapable of existing in a crystallized state, without a portion of water; as, for example, carbonate of soda, and sulphate of iron. The proportion of water also is different in different cases.

No metal is soluble in any oxygen acid, until it be first combined with oxygen. If a metal, iron for instance, be immersed in any concentrated acid, which its attraction for oxygen cannot decompose, in sulphuric acid, for instance, no action can take place until the acid be diluted with water. When the water is added, a sufficient quantity of it is decomposed to convert the metal into an oxide, its hydrogen is set free; and if collected, will shew how much oxygen is combined with the metal. In the meantime, the protoxide of iron combines with the sulphuric acid, and produces sulphate of iron.

When the iron is immersed in an acid, the elements of which have not so strong an attraction for each other as the iron has for the oxygen, in nitric acid, for instance, the acid, and not the water, is decomposed. Instead of hydrogen, a large quantity of nitrous gas is liberated, and combining as it escapes with the oxygen of the atmosphere, produces an immense volume of dense red vapour.

Muriatic acid has no action on gold; with oxide of gold it combines. But the gold does not decompose water, and the acid has no oxygen to part with. Therefore, upon immersing gold in a mixture of muriatic acid and water, no change is produced. If some nitric acid be added, an action takes place; the nitric acid is decomposed, and a large quantity of nitrous gas escapes, a sufficient quantity of oxygen combining with the gold to convert it into an oxide. In the meantime, the oxide, as it forms, combines with the muriatic acid, not with the nitric. Upon evaporating the solution, crystals of muriate of gold only are produced.

The nitric acid, if any be left undecomposed, escapes during the evaporation.

It has been observed, that the quantity of oxygen in all oxides, and oxygen acids, is a definite quantity. So also in the solution of oxides with acids, to produce saline compounds, the proportions of the base and acid are always definite.

It further appears, that there exists a certain proportion between the oxygen combined in the oxide, and the oxygen combined in the acid, and that these proportions are variable with the acid.

Thus in the class of saline compounds called sulphates, the proportion of oxygen in the acid is 3 times that in the base. In the class called nitrates, 5 times; in carbonates, it is twice the quantity; the same in phosphates. So that the quantity of different bases which are required to saturate an acid, must be such as contains the same quantity of oxygen. But this law is a consequence of combination in definite proportions.

If it be wished to decompose sulphate of copper by metallic iron, when it is known how much oxygen is combined with the copper which is here in the state of a peroxide, it may be calculated how much iron the oxygen will convert into the state of a protoxide. If that quantity of iron be added, the copper will all be precipitated in the metallic state, and the iron all converted into green sulphate of iron, and no acid nor oxygen be left uncombined.

Another consequence of this property is, that when two oxides of the same metal, a protoxide, for instance, and a deutoxide, are capable of forming saline compounds with the same acid, the second oxide will require a larger quantity of the acid, in the same proportion in which it is combined with a larger portion of oxygen; so that the same proportions between the oxygen of the acid and the base is still preserved.

Acids combine with the same alkali or oxide, in some cases, in more than 1 proportion. In such cases, the proportion of acid, or base, is a multiple or submultiple of the quantity contained in the neutral compound. Thus are formed acetate and subacetate of lead or copper, sulphate and bisulphate of potash, carbonate and bicarbonate of potash or soda. The terms sub and super are often applied in these cases, and create no small confusion by their misapplication,

In many cases, two bases have the property of uniting in certain proportions, and of forming a double saline compound with a single acid. Magnesia and ammonia have a tendency to combine together with acids, and even to separate from them together. Thus we have phosphate of ammonia and magnesia; lactate of potash and soda. Generally, the bases of the double salt divide the acid between them. This disposition to form double salts is often a source of inaccuracy in chemical analysis, and frequently is an inconvenience in the chemical purification of bodies.

Some metallic salts owe their permanent existence to this double combination. Hydro-cyanate, or prussiate of potash, is a salt in which the acid is retained by a weak attraction, and is gradually decomposed. But the double salt, hydro-cyanate of potassa and iron forms durable crystals. The alkaline oxides shew a strong tendency to combine with the oxides which are not alkaline, in the formation of these double salts; and frequently, when they are used as precipitants of other oxides, a certain part combines and falls down in the insoluble precipitate. Thus platinum, when precipitated from a saline compound by an alkali, carries a small portion of the alkali and acid with it, forming sub-double salts.

When one metal is precipitated from a saline compound by another in its metallic state, the precipitated metal is completely separated from the acid and oxygen; but gene-

rally, it attracts a small portion of the precipitating metal into combination with it.

When one metallic oxide is precipitated by another, whether the precipitant be an alkali, an earth, or an oxide, the precipitate is more generally in the state of an insoluble subsalt; a portion of the acid being precipitated with it, and frequently a small portion of the precipitant.

Many of the oxides have an attraction for each other, when placed in favourable circumstances, and produce very strong combinations. It is limitted in saline and watery solutions, but often gives the chemist a good deal of trouble in analysing compound minerals; where, when one metallic oxide is precipitated, it is perpetually carrying with it a portion of another.

Thus silica frequently precipitates minute portions of alumina. Iron and alumina frequently attract each other. When lime is precipitated, a portion of magnesia, if present, is attracted by it. Magnesia also strongly attracts a portion of lime. Iron and manganese, cobalt and nickel, attract each other. In igneous fusion, these attractions act with much greater force.

In their pure state, many of the oxides, the different earths, for instance, are infusible, except at the most intense heat of the voltaic battery, and a few remain unchanged even in that. Some oxides readily part with their oxygen on the application of heat, others evaporate altogether. Many are readily fused at an elevated temperature, and are converted into glass.

Of these latter oxides, several have the property of promoting the fusion of those that are infusible alone, of combining with them, and of converting them into vitreous compounds, that are more or less transparent. In consequence of this property, they are called fluxes. Some of these fluxes have acid properties, and some alkaline, but many of them are neutral; and it is most probable their at-

tractions in general do not depend upon any acid, or alkaline agency, any more than the attraction of sulphur does in the production of sulpurets, or the attraction between lime and magnesia do in the precipitation above cited, and in numerous similar cases.

By a proper selection and combination of those bodies, a very curious, useful, and valuable class of compounds is produced, of which the various kinds of glass afford instances; and which are white, or variously coloured; opaque or transparent, according to the different oxides that are introduced, and the proportions between them.

M. Berzelius, one of the most able chemists of the present day, and some others with him, consider these bodies as saline compounds of acids and alkaline oxides.

Silica is very generally an ingredient in both native and artificial compounds; and, therefore, from its analogy, has been called an acid, and its compounds by some chemists silicates. There are vitreous compounds, in which no known acid nor silica is present. When alumina is present, it becomes an acid for the occasion, and thus we have aluminates of iron, aluminates of lime, aluminates of magnesia. By the same reasoning we must have plumbates and cuprates of soda, plumbates of copper, cuprates of lead, and other such confused names. Thus, our cups, pans, and glasses, become neutral or acid salts,—silicates of alumine, iron, lead, soda, &c. The topaz and sapphire are aluminates of lime and iron.

There are, doubtless, many compounds containing an acid as an essential ingredient, that are insoluble in water, and vitrifiable: but to make an acid of one of the ingredients in every compound, for the sake of analogy, seems to be carrying the analogy so far as to create apparent contradiction and confusion, while the meaning of the word acid is lost in the generality of its application.

Here is another instance of the difficulty that attends

the application, of our strictly logical definitions, to the subjects of the material world.

Of all chemical properties of bodies, the properties of acid, and alkali, appear, at first sight, most opposite, and most distinctly marked; and consequently their distinctive properties most easily defined. As the chemist advances in his researches, he finds the acids gradually vary in properties, and one distinctive property after another fades, and at length disappears. The same gradation extends through alkalies, alkaline earths, and oxides; so that, at last, the property of two oxygen compounds to combine, and produce a crystalline combination, is considered as a sufficient test of one being acid, and the other alkaline.

This generalization of the term acid and alkali annihilates their primitive meaning, and renders them mere relative terms, that are almost undefinable—equivalent to positive and negative in electricity.

The chemical attractive force between the metals and clorine, is stronger than between them and oxygen. It acts upon most metals at the usual atmospheric temperature. If copper-foil, arsenic, zinc, or antimony, in powder, are introduced into a vessel full of chlorine gas, at the atmospheric temperature, they inflame, burn, and a rapidly combined into chlorides.

When an oxide is heated in chlorine, in most cases it is decomposed, and a chloride formed. Insoluble chlorides are sometimes conveniently formed by the addition of soluble oxy-salts; that is, salts containing the base in the state of oxide. Thus, nitrate of silver may be precipitated with chloride of sodium by fusion, or muriate of soda by solution, and in either way an insoluble chloride of silver forms.

Many of the metallic chlorides are decomposed by other metals, that have a stronger attraction for chlorine.

Water and the chlorides decompose each other by a complex attraction; the chlorine combining with the hydrogen of the water, and the metal with the oxygen.

Some of the metals form more than one compound with chlorine, as well as with oxygen, in which case the second compound is a multiple, or submultiple, of the first.

Some metals decompose muriatic acid, forming a chloride, and liberating the hydrogen.

When the oxides of metals are heated with muriatic acid, generally they combine; but when the water is evaporated, a decomposition follows; a chloride is produced, and the oxygen of the oxide combining with the hydrogen of the acid, form water, and evaporate.

Chlorides, like oxides, differ widely in their properties. They are of all colours. Some are decomposed by heat, others unaffected. Some are insoluble in water, others soluble. Those which are soluble decompose water, the chlorine attracting the hydrogen, and becoming muriatic acid; while the base attracting the oxygen, becomes an oxide; the chloride of the metal thus becoming a muriate of the oxide. On the other hand, some few metals decompose muriatic acid, and thus become chlorides, the hydrogen being evolved.

The metallic oxides form compounds with chloric acid. When the chlorates are heated, the oxygen is liberated, and a chloride produced.

Iodine combines with some of the metals, forming protiodides and periodides, all of which are little known. Sometimes, when water is present, it is decomposed, and hydriodates formed. They are very analogous generally to chlorides.

Hydrogen combines with arsenic and tellurium, forming two solid compounds termed hydrogurets, and two gasses, which are analogous to sulphuretted or phosphuretted hydrogen. At a high temper[illegible] it dissolves potassium,

zinc, and some other metals, but deposits them as it cools.

Hydrogen has the power of attracting the oxygen from some oxides, in which it is retained by a weak affinity, producing water. In some cases it attracts one portion, or multiple of the oxygen, reducing the oxide one gradation only; in some cases the metallic state is restored; but in the greater number of cases, the metal has a stronger attraction than hydrogen has, and a protoxide is produced.

Carbon combines with iron, forming two compounds, steel and plumbago; but it has little attraction for any other metal, as far as is known,

Cyanogen combines with many of the metals in a manner analogous to chlorine and iodine, forming a peculiar class of compounds, called cyanides, or cyanurets, which are readily converted into hydrocyanates of the oxides.

Sulphur has the property of combining chemically with all the metals, frequently producing combustion. The compounds are called sulphurets. It is attracted by different metals, with different forces. Some attract it strongly; silver, for instance, attracts it with great force; when exposed to an atmosphere, containing ever so minute a portion, it attracts and combines with it, producing a sulphuret. It is this sulphuret that tarnishes, and at length blackens the surface of silver that is left exposed to the atmosphere.

Sulphurets are, like oxides, chlorides, and iodides, definite compounds, combined generally in one or two proportions; sometimes apparently in more.

Some few are produced at the atmospheric temperature; some by heating the metals and sulphur together; some more conveniently by decomposing the sulphates by heat and charcoal; some by the double decomposition of their oxides and sulphuret[illegible] hydrogen.

Native sulphurets of different metals are met with, some of them very abundantly.

The experiments of Berzelius lead to the opinion that sulphur combines with the metals, in numerous proportions. But his experiments, as well as the recent experiments of M. Berthier, shew, that the proto- and bisulphurets are the most permanent compounds. The latter chemist shews, that the proto-sulphurets are readily prepared from the neutral sulphates, as steel is, by cementation. That is, a known weight of the sulphate, to be decomposed, is to be placed in a crucible, lined with charcoal, covered with it, and the cover being luted on with clay, exposed to a white heat as long as is sufficient to fuse the product, and convert it into a sulphuret, the oxygen escaping.

When the base or the sulphuret is not volatile, as when sulphate of baryta, strontia, or lime, is the subject of experiment, the quantity lost will exactly equal the weight of the oxygen that was combined with the base and acid.

The sulphurets are very different in appearance from the respective metals. The peculiar lustre, opacity, and polish, are lost in the artificial compounds; but sometimes remain in the native in a diminished degree. They are generally variously hard and brittle, and variously coloured. Some are fixed in a strong heat, although both the elements are volatile, as sulphuret of potassium; others are volatile, as sulphuret of mercury; some, when heated, part with a portion of their sulphur; and others, as gold and platinum, part with the whole of it. Some sulphurets, when heated in open vessels, are not affected by the atmospheric air; others absorb oxygen, the sulphur escapes in the state of sulphurous acid, and the metal is converted into an oxide, as in the roasting of metallic ores.

This decomposition, where the metals have a strong attraction for oxygen, takes place at the temperature of the atmosphere, on the addition of water.

Thus when native sulphuret of iron is collected, and spread out to the air and rain; oxygen is absorbed, caloric evolved, and sulphate of iron produced. It is thus that all the sulphate of iron consumed in this country is made.

In general, when metallic oxides combine with sulphur, they part with their oxygen, which is attracted by a portion of the sulphur, and forms sulphuric and sulphurous acid. In a few cases they appear to form sulphuretted oxides, but it is doubtful whether they form definite compounds, and if they do, the affinity is very slight between the sulphur and the oxides.

Acids and water act on sulphurets differently, according to their different properties. The acid, or water, or both, may be decomposed, as well as the sulphuret, and the resulting actions are sometimes very complicated.

The elucidation of these actions, and their results, constitutes one of the most abstruse parts of chemical science.

The sulphurets, like the acids and chlorides, may be decomposed, or their bases changed, by another metal that has a stronger attraction for the sulphur. Thus sulphuret of mercury may be decomposed by iron, and the metallic mercury produced.

Sulphuretted hydrogen combines very generally with metallic oxides, forming a class of salts, called hydrosulphurets, or rather hydrosulphuretted oxides.

When a metallic oxide solution is acted on by sulphuretted hydrogen, the result differs in different cases.

If the force of attraction between the metal and oxygen be slight, a double decomposition ensues, water is formed, and a pure metallic sulphuret. In some few cases the metals are reduced. When, on the other hand, the metal has a strong attraction for oxygen, a secondary compound is produced, or a hydrosulphuret of the metallic oxide, in which the sulphuretted hydrogen acts the part of an acid, and, like other acids, combines in definite proportions.

The greater number of the precipitates produced in metallic salts by sulphuretted hydrogen, are, in fact, sulphurets, or readily become so on the application of heat. They are mostly insoluble without decomposition, and have peculiar characteristic colours.

Thus,	Antimony is precipitated .	orange coloured
	Arsenic	yellow
	Bismuth	black
	Cadmium	orange
	Copper	black
	Gold	yellow
	Lead	black
	Mercury	black
	Molybdenum	brown
	Platinum	metallic
	Silver	black
	Tin	brown
	Zinc	yellow

Ferrocyanic acid, a compound hereafter to be spoken of, also produces insoluble compounds with many of the metals, which compounds are known by their peculiar colours.

Carburet of sulphur may be combined with many of the metallic oxides, producing carbosulphurets.

A considerable number of the metals combine with phosphorus, forming the metallic phosphurets. Some are formed by heating the phosphuret and metal together, others by heating the metal with phosphoric acid and charcoal. They are moderately fusible, capable of crystallizing, and decomposable at a high temperature. They are of no use.

From some of the metallic oxides phosphorus attracts the oxygen.

Boron may be combined with several of the metals, but the compounds are little known.

The metals are very generally capable of combining with each other, and frequently modify each other's properties to a considerable extent.

In this manner a very great number of valuable and useful alloys are produced, and employed in different manufactures and arts. They are generally united by simply fusing them together, but various other manipulations are often necessary. They appear, for the most part, to admit of being united in indefinite proportions; but there appear to be certain definite proportions in which they combine more strongly, so as to produce more complete compounds; many of which form regular crystals. When a part of an alloy is, by rest and long fusion, free to separate from the general mass, it will frequently do so, and produce a definite compound.

When zinc and copper are united to form brass, a certain quantity of the zinc will not separate. The surplus is easily evaporated.

In precipitating one metal by another, alloys, consisting of different proportions of the metals, are frequently produced.

The specific gravity of the alloys is sometimes the mean of the two metals. In some cases the density is increased; in others diminished. Thus, according to M. Thenard, the following alloys possess a specific gravity that is heavier than the calculated medium of the two metals.

Gold and Zinc	Silver and Zinc
Tin	Lead
Bismuth	Tin
Antimony	Bismuth
Cobalt	Antimony

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Copper and	Zinc	Lead and	Bismuth
	Tin		Antimony
	Palladium	Platinum and	Molybdenum
	Bismuth	Palladium and	Bismuth.
	Antimony		

And the following alloys possess a specific gravity that is lighter than the calculated medium.

Gold and	Silver	Iron and	Bismuth
	Iron		Antimony
	Lead		Lead
	Copper	Tin and	Lead
	Iridium		Palladium
	Nickel		Antimony
Silver and	Copper	Nickel and	Arsenic
Copper and	Lead	Zinc and	Antimony.

In both cases there are certain proportions in which the density or rarity of the respective alloys are at their maximum.

Alloys are, for the most part, more fusible than the metals composing them, or at least more fusible than the mean proportion. Thus, platinum is a most infusible metal, the alloy with arsenic is very fusible. Its alloy or amalgam with mercury is very fusible also. An alloy of certain proportions of lead, tin, and bismuth, melts when dropped into boiling water, being much more fusible than either of the metals.

Malleability and ductility are usually impaired by mixture. Thus, lead or tin render gold brittle. A grain of lead will totally destroy the ductility of an ounce of gold. An alloy of platinum, copper, and zinc, form a compound, which is ductile and malleable: a grain of iron, it is said, will render half-a-pound of it brittle. A very small quan-

tity of copper is found to improve the laminability of gold; but hardens it, and, in certain proportions, the alloy is harder than copper. A small addition of silver renders gold much harder than either of the two metals.

It is for the purpose of rendering gold harder, and better fitted to resist the necessary wear, that a certain regulated proportion of copper or silver is allowed, by law, in this country, to be mixid with it, thus establishing what is called standard gold.

The alloys are often much changed in colour. The colour of brass is very different from copper or zinc. Copper is rendered quite white and brittle by a very small quantity of arsenic. Eight per cent. or more of nickel appears to whiten copper without destroying its tenacity.

The volatility of the most fixed metals is easily increased by alloying them. If an alloy of gold and mercury is distilled, a part of the gold passes over with the mercury.

The tendency of many metals to combine with oxygen is increased by their being alloyed. An alloy of lead and mercury, or lead and tin, has an increased affinity for oxygen. But in some cases the affinity for oxygen is diminished in the alloys.

The action of acids on alloys is modified by the properties of the respective metals. Gold, when alloyed with a small proportion of silver, defends it from the action of nitrous acid. When the silver is increased so as to form a fourth part, as it is by the gold-refiners in the process of quartation, the silver is completely dissolved in nitrous acid, and the gold left pure and porous.

The uses to which the metals have been applied, by man, are as numerous as their known properties. According to their respective properties, and according to the numerous, and various wants of science, and civilized society, they have been applied in every possible way. They have in consequence given origin to numerous useful

arts. Without them many of our most valuable and extensive manufactories would have remained in a low state, and many of the most valuable and elegant branches of science must have continued in infantine imbecility.

Section II. *Of the Metals producing Alkalies and of their Compounds.*

Article 1. Potassium.

§ 1. The body called potash has been well known and extensively used for ages past. It occurs frequently in the state of a mineral combined in various mineral substances. It is chiefly obtained from vegetables, the greater number of which contain it, by burning them, and lixiviating their ashes. But that it is a compound body of a peculiar metal, and oxygen, is a recent discovery, one of the first fruits of the application of that powerful instrument of analysis, the voltaic pile. The metal was discovered by Sir H. Davy, in 1807.

When a piece of pure potash, or hydrate of potassa very slightly moistened is placed between the platinum, or gold wires of a voltaic battery, consisting of from 100 to 200 series of double plates; the potash at the points of contact with the wire becomes fused, at the positive pole oxygen is liberated, with effervescence; at the negative small bubbles of a bright metal, resembling quicksilver in colour, appear. These globules, if they touch any moisture, burn with explosion; and are converted into potash again. If left exposed to dry air, they rapidly become covered with a white crust, which protects them for a short time, from further change.

Messrs. Gay-Lussac and Thenard soon after discovered a method by which this metal may be collected in larger

quantity, by the application of a combination of chemical attractions.

A gun-barrel, or a tube of pure iron, a little contracted at one end, is to be bent to an obtuse angle, at a few inches from the smallest end; and again near the middle in an opposite direction. The surface of the middle part of the tube is to be coated with stiff loam, it is then to be partially filled with iron turnings, leaving a free passage for the gasses produced within the tube. In the tube, above the upper angle, are to be placed lumps of pure dry hydrate of potassa. The coated part of the tube is then placed across the centre of a small blast furnace of such dimensions, that the angles may be near the opposite sides, and the upper arm containing the potash be left free. A receiver must now be adapted to the lower end, and kept cold; and both extremities of the apparatus must be made air-tight; which is best accomplished by cementing into the upper extremity of the iron tube, and into the opening in the receiver, glass tubes, bent downwards; and immersing their lower ends to different depths in mercury. The fire is now to be raised to a white heat. Then by heating, with a small crate of burning charcoal, the part of the tube containing the potassa, it is very slowly melted, and descending comes in contact with the intensely heated iron. The iron instantly decomposes the water of the hydrate. By the joint attraction of the newly evolved hydrogen for the potassium; and of the intensely heated iron for the oxygen, the potassa is decomposed; a gaseous hydruret of potassium is formed, and passes on towards the receiver, where upon its loss of temperature the metallic potassium precipitates, and the pure hydrogen escapes.

This process requires a little attention, and delicacy in the management; but otherwise is as simple and easy, as the arrangement is beautiful.

Potassium is an opaque white brilliant metal, in lustre

and appearance resembling mercury. Its specific gravity is about 0.865; its equivalent or atom is fixed at 40.

At the atmospheric temperature it is ductile and soft. It cuts, and may be kneaded like wax. At 320° it is hard and brittle; at about 150° it fuses. In close vessels, it may be distilled at a red heat. It is a good conductor of electricity, and of heat. On account of its strong attraction for oxygen, it is requisite to keep it immersed in some gas or liquid, which has no oxygen combined in it. It is usually kept under naptha. It has a more powerful attraction for oxygen than most of the known elements.

When potassium is exposed to atmospheric air, the oxygen quietly acts upon the surface, and it is soon covered with a coat of oxide; after which the action proceeds more slowly.

A similar effect is produced by dry oxygen. If, like common air, it contain hygrometric vapour, the action is more rapid. If heat be applied, the metal takes fire, and burns with a brilliant white flame.

When potassium is brought into contact with water in a confined vessel, it decomposes the water with great energy, evolving hydrogen, and producing heat and noise, but no light.

When a lump of potassium is thrown upon the surface of water, exposed to the atmosphere, it instantly takes fire, burns, scintillates, throws out brilliant sparks, and flies about, decomposing the water with great energy. The quantity of flame is increased by the hydrogen, as it is liberated, instantly being inflamed, and combining again with the oxygen of the air. It appears that the hydrogen, as it is disengaged, dissolves a portion of the potassium; a white smoke is formed, which as it ascends gradually extends, and is common potash. The greater part of the oxide of potassium that is formed of course dissolves in the water.

When placed upon a piece of ice, potassium instantly takes fire, and burns with a bright flame, leaving a deep hole in the ice.

§ 2. Potassium has the power of combining with oxygen in two proportions.

Protoxide of Potassium, or Potassa, may be obtained from the hydrated protoxide, or common potash, by the superor attraction of iron, at a very high temperature, for the oxygen of its water. A quantity of dry protoxide of potassium is always produced in the operation for obtaining potassium. It is a hard greyish substance, which absorbs water, and slowly becomes converted into a hydrate.

Dry protoxide of potassium appears to consist of potassium 1 atom 40, + oxygen 1 atom 8; = 48. The dry hydrate of potassa is a white crystalline body, known under the name of pure potash, and consists of dry protoxide of potassium 1 atom 48, + water 1 atom 9; = 57.

This body is usually obtained by decomposing a solution of the carbonate of potassa, by means of fresh burnt lime, which has a stronger attraction for the carbonic acid than potassa has, then rapidly evaporating the solution to dryness in a silver vessel. It absorbs water with some force, and is very deliquescent.

Pure hydrate of potassa, caustic alkali, potash, or soap ley, acts upon, and combines so energetically with all animal and vegetable matter, that it requires some precaution to prepare it perfectly pure.

It is an extremely acrid and corrosive substance. It melts at a red heat, and at a bright red heat still retains a portion of its water, and evaporates with it, forming an acrid white smoke.

It may be crystallized in octoedrons; it is extremely deliquescent. The fused potash evolves heat on mixture with water. The crystals generate cold, and still more so on mixture with snow.

When diluted with water, it has a disagreeable peculiar taste, called alkaline. If touched, it dissolves the surface of the curticle, producing a soapy feel.

It changes vegetable reds to blue; the colour of violets and red cabbage to green; the yellow of turmeric to a brown. It combines with oils and fats into soaps, and has all the properties called alkaline in a most eminent degree.

Potassa has very extensive chemical agencies, and, in consequence, is very extensively used in chemistry, and in various arts, and manufactures.

§ 3. *Peroxide of Potassium* is produced by heating the metal in an excess of oxygen gas. It burns with intense heat and light; and produces an orange coloured compound, which appears to consist of

Potassium 1 atom 40, + oxygen 3 atoms 24; = 64.

When mixed with water, oxygen is given off with effervescence, and a solution of the hydrated protoxide is obtained.

§ 4. Potassium burns in chlorine with great vividness, and produces a *chloride of potassium*.

Potassium, exposed in muriatic gas, decomposes the gas producing the same compound, and setting the hydrogen free. It may be obtained more abundantly by heating muriate of potash; when the oxygen of the potash and the hydrogen of the acid will combine, and produce water, which the heat will volatilize. It consists of

Chlorine 1 atom 36, + potassium 1 atom 40; = 76.

It is soluble in three times its weight of water. During the solution, a portion of the water is decomposed, and combines with the two elements respectively, thus producing a muriate of potash, as this salt is usually called.

In this case, an atom of hydrogen unites to an atom of the chlorine, forming muriatic or hydrochloric acid; and the atom of oxygen thus liberated unites to the potassium, forming potassa.

Thus the dry salt consists of muriatic acid 1 atom 37, + potassa 1 atom 48; = 85.

Hydrochlorate, or muriate of potash, crystallizes in cubes.

§ 5. *Chlorate, or oxymuriate of Potash,* is commonly prepared by passing chlorine through a solution of carbonate of potassa, distributed in a set of Wolfe's bottles. The chlorine decomposes the carbonate, and combines with the potassa, at the same time decomposing a portion of water, and combining with its elements, in such proportions as to produce both hydrochloric and chloric acids in the proportions of five atoms of the former to one atom of the latter. The acids combine with their respective proportions of potassa, and produce two compounds.

The chlorate of potassa, being less soluble, crystallizes in white shining scales, that may be purified by re-dissolving and re-crystallizing them. The compound left in the liquor is muriate or hydrochlorate of potassa.

Chlorate of potassa appears to consist of 1 atom of potassa, 48 + 1 atom of chloric acid 76; = 124. It is soluble in about 17 parts of cold water and in about 2½ of boiling water, and the solution has a cool austere taste.

The dry salt exposed to heat decrepitates, melts, and gradually gives out its oxygen very pure, a chloride of potassium remaining.

It is decomposed, with violence, by many inflammable bodies, on a slight increase of temperature. The small quantity of two grains, rubbed with half as much sulphur, by means of a pestle of wood, will produce a violent explosion. If wrapt in paper and struck, the detonation is more violent.

Rubbed alone, this salt is phosphorescent.

With charcoal, the effect is nearly the same as with sulphur.

When mixed with sugar, or with any inflammable compound, it takes fire on being touched with sulphuric acid.

A composition of this kind is applied to the extremities of the matches now employed in what are called instantaneous light boxes. The best matches are those previously dipt in sulphur.

It has been proposed by different chemists, to employ this compound in the manufacture of gunpowder; but the property which its mixtures with combustibles have, of exploding when heated to a temperature much below a red heat, renders it totally unfit for the purpose. Attempts, not very wisely, have been made, and fatal consequences have followed them. One of the most valuable properties of common gunpowder, and without which it could not safely be made or moved, is, that it requires a red heat to explode it.

§ 6. *Perchlorate of Potassa* is obtained by adding to 1 part of chlorate of potassa 3 parts of sulphuric acid and, after the violence of the action is over, exposing the mixture to a gentle heat, until it becomes white. A bisulphate, and a perchlorate of potassa, are formed, and may be separated by solution and crystallization; the bisulphate of potassa being very soluble, and the perchlorate requiring 50 times its quantity of water to dissolve it.

It appears to consist of potassa 1 atom 48, + perchloric acid 1 atom 92; = 140.

It crystallizes in long octoedrons. It is insoluble in alkohol.

It is decomposed and parts with its oxygen when heated to about 412°.

It is decomposed by sulphuric acid, and the perchloric acid distils over it at about 280°.

§ 7. Potassium and iodine combine when heated together. The combination is attended with the evolution of heat and light. It seems to consist of potassium 1 atom 40, + iodine 1 atom 25; = 165.

It is a white crystallizible body, which readily melts, and

is volatilized at a heat below redness. It is soluble in water, and during the solution it acts on a portion of the water in the same manner as chlorine does, and both are decomposed. The iodine combining with the hydrogen, forms hydriodic acid; and the potassium with the oxygen forms potassa. The secondary elements combine, and form a neutral hydriodate of potassa.

Iodate, and at the same time *hydriodate of potassa*, are produced by adding iodine to an aqueous solution of potassa, as long as the solution continues colourless. A part of the water is decomposed: the hydrogen is attracted by one portion of iodine, the oxygen by another; and both combining with their respective portions of potassa, produce the two salts in question. The iodate falls down in granular white crystals, which require nearly 14 parts of water for their solution.

It consists of iodic acid 1 atom, + potassa 1 atom.

The hydriodate which is left in solution is separated in crystals upon evaporation; or they may be separated by evaporating the mixture, and heating it with alkohol, which dissolves the hydriodate only. It is a very soluble deliquescent salt, consisting of hydriodic acid 1 atom, + potassa 1 atom.

It melts and evaporates at a red heat in the state of an iodide of potassium.

§ 8. Potassium, when heated with hydrogen, absorbs a portion of it, producing, according to Messrs. Gay-Lussac and Thenard, a grey hydruret, that inflames when heated. When exposed with hydrogen to a white heat, a temporary gaseous combination is produced, as has been shewn. On coming into the air, it instantly inflames.

§ 9. *Nitrate of Potassa*, saltpetre, or nitre, is a salt produced in great quantities both naturally and artificially. It comes to this country in a very impure state from the East Indies, where it is a natural production, obtained by

washing certain soils. In France, and on the continent of Europe, it is obtained abundantly, by preparing and spreading out to the atmosphere, certain mixtures of old lime rubbish, mixed with decaying animal and vegetable matters, thus forming what are called nitre beds, the soil of which is occasionally washed.

The acid appears to be produced by the complicated play of chemical attractions that takes place between the elements of the atmosphere, of the water, and of the decaying matter. As the nitrous acid is formed, it is instantly attracted into combination with the alkalies or lime that are presented to it, and thus its escape or decomposition is prevented. The artificial nitre beds are considered as strong in nitre when they produce five per cent. of salt. The nitrate of lime is readily decomposed by sulphate of potassa. The muriate of soda, sulphate of lime, and other impurities, are then separated by repeated crystallization.

Pure dry nitrate of potass consists of pure potassa 1 atom 48, + nitric acid 1 atom 54; = 102.

It has a cooling taste. It dissolves in 7 times its weight of water at 60°, and in its own weight of boiling water. Its solubility is increased by the addition of a little common salt. It is crystallizable in six sided-prisms terminated by diedral summits. The crystals do not contain any combined water, but a little water is found entangled in their interstices, which gradually evaporates. They melt at a moderate heat, gradually dry, and readily part with a portion of oxygen, as the temperature rises to a red heat. In this state nitre is cast into moulds, and sold in commerce under the name of sal prunella.

At a red heat, it gives off a large quantity of very pure oxygen; at white heat, it is wholly decomposed.

At a red heat it is rapidly decomposed by almost all combustible bodies; by some of them the oxygen is attracted with great violence, and the bases highly oxidated.

When three parts of nitre are heated with two of carbonate of potassa, and one of sulphur, the mixture melts, and at length explodes with a loud report.

§ 10. *Gunpowder* is a mechanical mixture of this salt, with sulphur and charcoal. The proportions differ, within a certain limitation, at different powder-mills, and are as much as possible kept secret.

The most general proportions are from 75 to 78 parts of nitre; from 12 to 15 of charcoal; and from 10 to 12½ of sulphur; so that the quantity of oxygen liberated by the decomposition of the nitre, is in general considerably greater than is necessary to saturate the charcoal and sulphur.

The explosion of gunpowder is not instantaneous, like chloride of nitrogen, or many other fulminating compounds; but the particles explode in a succession, more or less rapid, as powder is more or less confined, or pressed together; and generally a part of the powder escapes, or is driven away undecomposed. The more rapid this succession is the more powerful is the powder. But if the explosion could be rendered instantaneous, the danger from the bursting of fire-arms would be very great. The successive evolution of its force upon the sides of the confined chamber of the gun, affords time for their elasticity to re-act, and throw the whole elastic force upon the weakest and yielding part, that is upon the loading of which the re-action is relatively slight and rapidly diminishing, until the explosion is complete.

If gunpowder be exploded in small successive portions over mercury, the gasses collected will be nitrogen, carbonic oxide, carbonic and sulphurous acid, and a little sulphuretted hydrogen. The potassa of the nitre will be mixed with some charcoal and a little sulphur. But the results will vary a little according to the temperature at

which the explosion takes place. The expansion of the gasses is doubled for every 480° of temperature. It is essential that the ingredients be most impalpably powdered, and intimately mixed. The mixture is then moistened, beat into a cake, dried a little, broken up, and granulated, thoroughly dried, and polished. It is said, that if mixed with powdered glass, or any substance of similar hardness, and struck with a hammer, it explodes. Whatever cause shall excite a red heat, at the point of contact with a single grain, explodes the whole of it.

§ 11. *Carbonate of Potash*, commonly called sub-carbonate, particularly in the London Pharmacopia, pearlash, potash, woodash, salt of tartar, salt of wormwood, are all the same salt, differing in purity only.

It is obtained in great abundance by the extensive calcination of vegetable matter. Therefore, it is manufactured in countries covered with wood, perennial and annual vegetables of no other use. The American pearlash, which is chiefly consumed in this country, is readily purified for common use by solution in an equal weight of boiling water, the crystallizable salts and some silica separating as it cools; from which it may be decanted.

It may be obtained more pure by burning purified tartar, or tartar and nitre together, or by decomposing the bicarbonate with caloric.

It consists of 1 atom potassa 48, + 1 carbonic acid 22; = 70. This salt is deliquescent, and very soluble in water; the concentrated solution is consistent like oil. Its taste is acrid and alkaline, but milder than that of the pure alkali. It readily melts, and bears a red heat without being decomposed. It changes vegetable reds to blue, turmeric yellow to brown, and has the other properties peculiar to alkalies, but in a milder degree than pure potassa has. The most concentrated solution of it has the specific gravity of 1.54, and contains 13.8 per cent. of carbonate; that is,

about 8 atoms or equivalents of water to 1 of salt. This water evaporates at a temperature of 300°.

This compound is the source from whence the pure alkali is obtained by the manufacturer and the chemist, generally and extensively.

§ 12. The *Bicarbonate of Potash* is best prepared by passing carbonic acid gas slowly through the last mentioned salt in solution in three parts of water, until the absorption ceases.

By slow evaporation at a low temperature, it crystallizes into four-sided prisms with dicdral summits.

It consists of 1 atom of potassa 48, + 2 atoms carbonic acid 44; = 92, to which add water 1 atom 9; = 101 fo the crystals.

The taste of this salt is alkaline, but milder than that o the carbonate.

It is soluble in 4 parts of water at 60°. Boiling water partly decomposes it, and about one-fourth of the gas escapes with effervescence. At a low red heat it is further decomposed, and reduced to the state of a carbonate.

Both these salts are readily decomposed by most acids, the carbonic acid escaping with great effervescence. As the bicarbonate contains double the quantity of carbonic acid, so its decomposition produces the more effervescence.

The bicarbonate is chiefly used in medicine.

They are both readily decomposed by lime without effervescence; the lime being converted into chalk.

§ 13. Potassium combines with cyanogen when gently heated, absorbing about twice the volume of this gas that it does of oxygen to produce potassa. The compound is yellowish, and dissolves in water without effervescence, producing a solution of hydrocyanate of potassa.

Hydrocyanate of Potassa may be formed more readily by simply mixing hydrocyanic acid with pure potassa. It is very soluble, tastes alkaline, turns syrup of violets green,

It is a feeble compound, and is decomposed by carbonic acid, and by light and air. It precipitates protoxide of iron from saline compounds, at first of an orange colour, but by exposure to the atmosphere, the precipitate becomes of a deep blue.

§ 14. *Potassium* combines with *sulphur*, producing light and heat, and a grey sulphuret is produced.

When carbonate of potassa is fused with sulphur in certain proportions, without access to oxygen or water, a decomposition is produced. The carbonic acid escapes, three-fourths of the oxygen of the potassa combines with part of the sulphur, and produces sulphuric acid sufficient to form a sulphate with the remaining fourths of the potassa. The potassium thus set free combines with the remaining sulphur.

According to M. Berthier, sulphuret of potassium may be produced by cementation. Pure dry sulphate of potassa, when placed in the middle of a crucible, filled with charcoal, and the cover luted on, and exposed for a short time to a strong heat, parts with the whole of its oxygen to the charcoal, and becomes a sulphuret of potassium.

It is of a fine flesh-red, crystalline, semi-transparent; and hard to roast, that is, it is difficult to separate the sulphur by heat and air. It dissolves in water, giving out great heat, but nothing else.

When dissolved in muriatic acid, the solution is transparent, and sulphuretted hydrogen only is given out. It is composed of potassium 100 + sulphur 41.

Sulphur and potassium may be combined in more than one proportion; but from the difficulty of obtaining the compounds pure, and from the facility of their decomposition by water, oxygen, or hydrogen, they have been involved in great obscurity.

According to M. Berzelius, sulphurets of potassium may be formed with any definite proportion of sulphur from 1 to 10. The protosulphuret is of a cinnabar colour, is com-

bined with some force, and is, in consequence, comparatively difficult to roast, or to inflame. It attracts moisture, and forms a yellow liquid. It is soluble in alkohol. The sulphurets of potassium have no smell while dry, and are of a red or orange colour.

As the proportion of sulphur increases, the compounds are less permanent, and are decomposed by water, emitting sulphuretted hydrogen.

It is doubted by some chemists whether sulphuret of potassa cannot also be formed. The compounds usually called sulphurets of potash are heterogeneous mixtures, and vary according to the proportions of the ingredients.

Berzelius, and many other chemists who have laboured much on this obscure subject, say, that there is no definite sulphate of potassa, but that the sulphur expels the oxygen, and combines with the base.

A compound called sulphuret of potash is sometimes used in medicine.

In the London Pharmacopœia, one part of sulphur is ordered to be fused with two parts of subcarbonate (carbonate) of potassa. The Dublin College order equal parts; the Edinburgh, 2 of sulphur to 1 of potassa. During the combination, the carbonic acid escapes, and there is some loss of sulphur; a red liver-coloured mass is produced, called liver of sulphur, or sulphuret of potassa. It may be formed in other proportions also, but it cannot be produced by solutions in water. A complicated action takes place on the addition of water to these sulphurets, which has not yet been clearly elucidated, although it has engaged the attention of the most able chemists. A part of the water is decomposed, sulphuretted hydrogen is produced. A hydrobisulphuret of potassa is formed, and a compound, or rather mixture, of sulphur, and potassa mixed with sulphate of potassa, sulphite of potassa, and sometimes carbonate.

§ 15. *Hydrosulphuret of Potassa* is formed by trans-

mitting sulphuretted hydrogen through a solution of potassa. Large transparent crystals are produced, which are four or six-sided prisms. Its taste is acrid and bitter. It is deliquescent, and entirely soluble in water. It colours the skin green. It is soluble in alkohol. When exposed, it absorbs oxygen, and passes to a sulphite. It is decomposed by most acids, the sulphuretted hydrogen escaping, without any deposition of sulphur.

Its watery solution may, with care, be evaporated without decomposing it; but it is apt to lose hydrogen, and to absorb oxygen.

Hydrobisulphuret of Potassa is formed by boiling flowers of sulphur in a solution of potassa, or by digesting the hydrosulphuret with sulphur.

Potassa, or the oxide of potassium, combines with the hyposulphurous, and sulphurous acids, forming salts which are not of any use.

§ 16. *Sulphate of Potassa* is produced, and pretty extensively, in the chemist's laboratory, in several manipulations, particularly in the distillation of aqua-fortis and nitric acid. It may be formed by neutralizing sulphuric acid by carbonate of potash.

It consists of 1 atom sulpuric acid 40, + 1 atom of potassa 48; = 88.

It crystallizes in short six-sided prisms, terminated by corresponding pyramids. Its specific gravity is nearly 2. Its taste is bitter and saline. It is soluble in 16 times its weight of water at 60°, or in 4 times its weight of boiling water. It fuses at a red heat. It is decomposed by charcoal, and is not affected by sulphur.

§ 17. *Bisulphate of Potassa* may be produced by boiling sulphate of potassa in sulphuric acid. It crystallizes in delicate acicular crystals.

It consists of sulphuric acid 2 atoms 80, + potassa 1 atom 48; = 128.

Its taste is acid; it is soluble in twice its weight of water at 60°. It gives a red tint to vegetable blues. It is mostly obtained in the distillation of nitric acid. It is known in the amorphous state under the name of sal enixum, and is much used among artists for cleaning the surface of metals.

By the addition of ammonia, or its carbonate, to bisulphate of potassa, a triple salt may be formed, which crystallizes in brilliant plates.

§ 18. *Potassium* may be combined with *phosphorus* in a vessel freed from oxygen. The produce is a compound having the colour and lustre of lead, which appears to be a subphosphuret, containing phosphorus 1 atom 12, + potassium 2 atoms 80; = 92.

There appears to be also a phosphuret. It is of a chocolate colour, and consists of phosphorus 1 atom 12, + potassium 1 atom 40; = 52.

Hypophosphite and phosphite of potash may be obtained; phosphate, subphosphate, and super, or bi-phosphate, may be formed also. They are salts little known, and less used.

§ 19. Borate of potassa may be formed.

A *neutral* and a *bifluate of Potassa* may be formed by mixing the acid with carbonate of potassa. To obtain the neutral salt, the acid must be slightly in excess, and the excess expelled by ignition; but in attempting to crystallize it, an acid salt is obtained.

Bifluate of potassa, at a red heat, dissolves and combines with silica, no acid being disengaged.

Article 2. Sodium.

§ 1. This metal was discovered by Sir H. Davy, soon after the discovery of potassium. It may be procured from pure dry hydrate of soda, by the same means that potassium is obtained from potassa, but rather less easily, from its slight attraction to hydrogen.

Its equivalent is 24. Its specific gravity 0.97.

It is a white brilliant metal, very much resembling potassium. It is malleable at a lower temperature than potassium, and may be pressed or welded together. It is so soft as to be easily spread out into a thin surface. It fuses at 190°, and is volatilized at a strong red heat. Its attraction for oxygen is very great.

Exposed to the atmosphere, it becomes tarnished and covered with a crust of oxide, but more slowly than potassium. It is not acted on by dried air until heated.

It combines with pure oxygen slowly, at the atmospheric temperature. When heated to redness, the combination is rapid, with scintillation, a white flame, and the production of a portion of peroxide.

When thrown into water, a strong effervescence and hissing is produced, by the decomposition of the water; and hydrogen gas is evolved, but does not inflame. When the water is heated, the decomposition is more rapid, with occasional scintillations.

In its general affections, it is very similar to potassium; but it acts with somewhat less energy.

Sodium appears to be capable of producing three oxides.

If sodium be fused with pure dry soda, they unite and produce a dark brown fluid, which coagulates into a dull brittle solid on cooling. It appears to be a suboxide. It attracts oxygen from the atmosphere, and decomposes water with effervescence.

§ 2. The pure dry *Oxide of Sodium*, or *Soda*, is obtained by heating sodium in a due proportion of dry air. It is of a light grey colour, has a vitreous fracture, melts in a bright red heat, and has a very strong attraction for water.

It consists of sodium 1 atom 24, + oxygen 1 atom 8; = 32.

It absorbs a certain quantity of water producing heat, and holds it, as potassa does, with great force, forming an

hydrated oxide, consisting of soda 1 atom 32, + water 1 atom 9; = 41.

This hydrate of soda is a white crystalline body. It cannot be decomposed by heat. It is generally obtained by decomposing the carbonate of soda with lime, in the same manner in which pure hydrate of potassa is obtained.

Its properties are very analogous to those of potassa. It is rather less energetic in its action, and, as we shall see, differences are observable in their respective compounds. When heated with potassium, it is decomposed, and the sodium sublimed.

Hydrated oxide of sodium, or soda as it is called, is distinguished from potash by its forming a carbonate which crystallizes readily and effloresces in the air, while potash forms a deliquescent one that is difficult to crystallize.

If tartaric acid be added to a moderately strong solution of potassa, cream of tartar is precipitated in small granular powdery crystals. With solution of soda, it produces no such precipitation.

Muriate of platinum is precipitated by a solution of potassa, but not by soda.

§ 3. *Peroxide of Sodium* is produced when sodium is exposed to heat, with an excess of oxygen.

It appears to consist of soda 2 atoms 48, + oxygen 3 atoms 24; = 72.

It is of a deep orange colour, and fusible. It deflagrates with combustibles, and is a non-conductor of electricity. When acted on by water, the excess of oxygen escapes, and hydrate of soda is produced.

§ 4. *Chloride of Sodium.* When sodium is heated in chlorine, it burns, producing a white compound, which has a pure saline penetrating taste.

When sodium is heated in hydrochloric or muriatic acid gas, the same compound is produced, and hydrogen liberated.

When soda is heated in chlorine, oxygen is given off, and a chloride of sodium formed.

When the compound of muriatic acid and soda, or muriate of soda, is heated, the hydrogen of the acid unites to the oxygen of the soda, forming water, which evaporates, and chloride of sodium is produced.

It consists of chlorine 1 atom 36, + sodium 1 atom 24; = 60.

When dissolved in water, and crystallized, it produces the well known body called common salt, hydrochlorate or muriate of soda. During solution in water, a portion of the water is decomposed, the oxygen combining with the metal, the hydrogen with the chlorine: thus they are converted into a muriate, consisting of soda 1 atom 32, + muriatic acid 1 atom 37; = 69.

Common salt is found in the solid state in immense quantities. Enormous masses occur in Spain, in Germany, in Cheshire, and at Cracow, and other places, where it is dissolved, purified, and crystallized for domestic uses.

When heated, it decrepitates. At a red heat, the water escapes, it fuses, and cools into a white solid mass, which is a chloride of sodium. It is soluble in 2½ of water. It is nearly equally soluble in hot water or cold.

Its crystals when procured by spontaneous evaporation are in solid cubes. As it is usually met with it is produced by rapid evaporation, at a boiling heat, and the crystals have the form of hollow quadrangular pyramids.

This salt is used as a condiment by all mankind when they can obtain it; and is licked with avidity by various animals. Where salt works or strong springs are not met with, it is prepared from the evaporation of sea water, and in some interior situations, it is obtained from very weak springs.

At Montier in Tarantaine there is an abundant salt spring, that contains not more than one and a half per

cent. of salt. About 2.250000 pounds of salt are produced from it annually.

The weak solution is concentrated to the strength of 22 per cent. by exposing an extended surface of it to the atmosphere. For this purpose, it is repeatedly run slowly over faggots. It is then evaporated by heat.

This salt is not acted upon by charcoal, sulphur, nor by any pure inflammable base, except potassium. It is decomposed by sulphuric and nitric acids, which attract its base.

It is decomposed also by carbonate of potassa.

Its uses are very extensive, not merely for domestic purposes, but in agriculture, in fisheries, and in various arts: in preparing Turner's patent yellow pigment, by the mutual decomposition of oxide of lead, and clorida of sodium; as a source of soda, of muriatic acid, and of chlorine.

It is an ingredient of sea-water, and is the principal preserver of its freshness; besides which, it protects and modifies its freezing, and increases its specific gravity.

§ 5. *Chlorate of Soda* may be obtained by the same process as chlorate of potassa, and differs but little from it.

An iodide, iodate, and hydriodate of soda may be obtained also, but are not applied to use.

§ 6. *Nitrate of Soda*, called also cubic nitre, crystallizes in short rhomboidal prisms. It is soluble in three parts of cold water. It has been proposed to use it in the manufacture of gunpowder; but its deliquescent property renders it unfit.

§ 7. *Carbonate of Soda*, the soda of commerce, the subcarbonate of the London Pharmacopœia may be obtained in various ways. It is met with native, in some parts of the world. It is procured in great abundance, by collecting and burning marine vegetables; and washing the ashes. Thus is produced the barilla which comes to Eng-

land from Spain, and the kelp that is prepared on the British coast.

The dry carbonate when pure consists of soda 1 atom 32, + carbonic acid 1 atom 22; = 54.

In the state of crystals, it consists of carbonate of soda 1 atom 54, + water 7 atoms 63; = 117.

The primitive crystal is an octaedron with a rhombic base of 60° and 120°. The crystals effloresce. The greater part of the water evaporates at a gentle heat.

Its taste is alkaline. It turns vegetable blues to green It is soluble in less than two parts of cold water, and has other alkaline properties.

§ 8. *Bicarbonate of Soda*, the carbonate of the London Pharmacopœia, is produced by passing carbonic acid slowly through a concentrated solution of carbonate of soda. The bicarbonate, as it forms, separates in flakes on account of its less solubility, and must then be dried in a temperature below 100°. It consists of soda 1 atom 32, + carbonic acid 2 atoms 44; = 76; to which add water 2 atoms 18 = 94 for the bicarbonate of commerce. Exposed to a low red heat the water escapes, and it is converted into a carbonate.

Boiling water converts it into a sesquicarbonate; one-fourth of its acid escaping with effervescence.

This salt is now used very extensively in soda water, and in the various effervescing powders, such as soda powders, seidlitz powders, &c. It is indeed the base of them. Their distinguishing property depends upon the bicarbonate giving out its carbonic acid, on the addition of a suitable proportion of tartaric acid.

A native sesquicarbonate of soda has been found at Fezzan in Africa. By the inhabitants it is called trona. According to the analysis of Mr. R. Philips, it consists of carbonic acid 3 atoms 66, + soda 2 atoms 64; = 130.

§ 9. *Sulphuret of Sodium* may be produced in the same

manner as sulphuret of potassium. According to Berthier, the sulphuret produced by cementation consists of sodium 100, sulphur 69.27.

It is most probable that sodium may be combined with larger proportions of sulphur.

§ 10. *Hyposulphite and Sulphite of Soda* may also be formed.

The first of these salts has the property of dissolving the muriate of silver. The compound thus produced has an intensely sweet taste, devoid of any metallic flavour.

§ 11. *Sulphate of Soda*, or Glauber's salt, is well known. It is produced in great quantity in the decomposition of common salt by sulphuric acid to obtain muriatic acid. The dry salt consists of 1 atom of sulphuric acid 40, + 1 atom soda 32; = 72. The crystals consist of 1 atom of dry salt 72, + 10 atoms of water 90; = 162.

This salt crystallizes in large octoedral prisms terminating in truncated pyramids.

The crystals are soluble in three parts of cold water at 60°, and in the water of their crystals at 212°.

They are efflorescent in the air, and readily part with above 50 per cent. of their weight in water.

The taste is saline, and nauseous. It is sometimes decomposed for the sake of the soda. It was largely consumed as a medicine, but its nauseous taste has caused it to be, in a great degree, superseded by sulphate of magnesia.

Bisulphate of Soda may be formed; and by neutralizing this with ammonia, a double salt is produced, an ammonia-sulphate of soda.

§ 12. A phosphite and hypophosphite may be formed also.

Phosphate of Soda is prepared by saturating the phosphoric acid obtained from bones, with carbonate of soda, evaporating and crystallizing the solution.

Its crystals are short rhomboidal prisms, with angles of 60° and 120°, terminated by a trilateral pyramid.

It consists of 1 atom acid 28, + 1 atom soda 32; = 60. The crystals, which effloresce, contain 60 per cent. of water. Hence, they consist of 1 atom of salt 60, + 10 atoms of water 90; = 150.

Phosphate of soda is soluble in four parts of water at 60°. It has a mild, simple, saline taste.

This salt is occasionally used in medicine as an aperient, chiefly on account of its comparative freedom from taste. Its action is weak and uncertain. Heat evaporates the water, and fuses it into a clear glass, which on cooling becomes opaque.

It is partially decomposed by sulphuric acid, and a biphosphate of soda produced; a still more soluble salt.

A Phosphate of Soda and Ammonia is found in human urine. It consists of acid 2 atoms 56, soda 1 atom 32, ammonia 1 atom 17; = 105.

It was formerly called microcosmic, or fusible salt. When heated, the ammonia escapes, and a biphosphate of soda remains.

§ 13. *Borate of Soda*, or borax, is found native in great abundance in India, from whence England, and Europe have long been supplied with it in an impure state. Lately, boracic acid has been found in great abundance in Italy; and it has become more economical to prepare borax from it.

Borax when purified or refined, is crystallized in regular hexaedral prisms, which effloresce slightly. 100 parts are said to consist of boracic acid 35.6, soda 17.8, and water 46.6.

Fluates of soda may be produced in the same manner as fluates of potassa, from which they do not materially differ.

The salts of soda are not precipitated by alkaline carbonates, nor by hydrosulphuret of ammonia, nor by ferrocyanate of potash. They do not, like salts of potash,

produce alum with sulphate of alumine; nor precipitate muriate of platinum.

Article 3. Lithium.

§ 1. Lithium was discovered so lately as in the year 1818, by Mr. Arfwedson, of Sweden, in a stony mineral called petalite. It has since been found in some few other minerals, to the extent of from 3 to 8 per cent.

To obtain it, we are told to powder the mineral finely; and, having mixed it intimately with pure lime, expose it to a strong heat. Dissolve the heated mass in muriatic acid, and evaporate to dryness, to separate the silica. Then add sulphuric acid, and apply heat until the muriatic acid has escaped. Dilute with water, and separate the sulphate of lime, by straining and pressure. Digest the solution upon carbonate of lime to separate the alumina, then filter and evaporate. The crystals of sulphate of lithia may easily be picked out from the sulphate of lime, and decomposed by baryta water, or by acetate of baryta or of lead; when the acetate of lithia may be converted into a carbonate by a red heat. The carbonate of lithia thus prepared may be converted into a pure hydrate by lime or baryta, in the same manner that carbonate of potassa is.

When submitted in the air, to the action of the voltaic battery, it is decomposed with bright scintillations; clearly affording a white opaque bright metal, which burnt rapidly, and instantly returned to the state of oxide.

The experiment appears to have been attempted twice only—by Sir H. Davy, and by M. Gmelin; probably on account of the scarcity of this substance.

The equivalent of lithium of course, is not known from direct experiment, but from indirect calculation it may be provisionally considered as 10, and the oxide as 10 + oxygen 8; = 18.

§ 2. *Lithia or Oxide of Lithium* is, like the other alkalies, corrosive, acrid, very soluble in water, and changes vegetable blues; it is sparingly soluble in alkohol.

§ 3. *Chloride of Lithium* is obtained by evaporating the muriate to dryness, and fusing it. It is a white semitransparent substance; soluble in water and alkohol, and very deliquescent. Heated in the atmosphere, it absorbs oxygen, loses chlorine, and becomes converted into lithia. It tinges the flame of alkohol red, and is crystallized with difficulty.

The action of iodine or its compounds on lithium have not been examined.

§ 4. *Nitrate of Lithia* forms soluble deliquescent rhomboidal crystals of a cooling taste. They are fusible and decomposed by heat.

§ 5. *Carbonate of Lithia* is obtained when concentrated solution of carbonate of potassa is added to sulphate of lithia. It falls down a powder, and is soluble in 100 parts of water at 60°. It consists of 54 acid, + 45.5 base in 100 parts. It is fusible, decomposes compounds of alumina, magnesia, ammonia and the metals.

§ 6. *Sulphate of Lithia* forms small white brilliant rectangular prismatic crystals.

Its taste is saline. It is more soluble than sulphate of potassa, and less so than sulphate of soda, 100 parts of the dry salt consist of 69.2 acid, 30.8 alkali.

A bisulphate is produced by adding an excess of acid. It is less soluble than the neutral salt, and more easily fused.

§ 7 *Phosphate of Lithia* is produced by the addition to sulphate of lithia, of phosphate of ammonia with an excess of ammonia. It is an insoluble compound. It is thus easily distinguished, and separated from potassa and soda.

Lithia then may be distinguished from the two other

fixed alkalies, by its greater capacity of saturation; by the insolubility of its phosphate, and carbonate; and by the great deliquescence of its nitrate and muriate.

Section III. *Of the Metals producing Alkaline Earths, and their Combinations.*

Article 1. Of Barium.

§ 1. Barium is another of those chemical elements, whose chemical attractions are so strong as to prevent its existing pure in a native state. But it exists in considerable quantity as a compound part of several varieties of a mineral, known under the popular name of heavy earth.

Barium was one of the metals first obtained by Sir H. Davy, by means of voltaic electricity. A portion of pure baryta obtained from the native carbonate, a mineral found in different parts of Britain; was first made into a paste with water, and placed on an insulated platinum tray. A small cavity in the paste held a globulæ of mercury. The mercury was rendered negative, the platinum tray positive by a voltaic battery of about 100 double plates. In a short time an amalgam formed, consisting of mercury and barium. It was introduced, under the vapour of naptha, into a small bent tube, made of glass free from lead: within which it was hermetically sealed. The mercury was then distilled over, and the barium remained insulated.

It is a solid difficultly fusible metal; of a lustre inferior to cast-iron; and of a dark grey colour. It sank instantly in phuric acid. When exposed to the air, it became instantly converted with a coat of baryta. When gently heated, it burnt with a deep red light. When put into water, a violent effervescence followed, and it disappeared; the water containing a solution of baryta.

§ 2. *Baryta or Oxide of Barium* is best obtained by exposing nitrate of baryta to a bright red heat for some time.

It appears to consist of barium 1 atom 70, + oxygen 1 atom 8; = 78.

It is of a greyish colour, and when pure very difficult of fusion.

Its specific gravity is about 4. Of the oxides called earths it is the heaviest. It is very poisonous, and so are almost the compounds of this metal.

It has a caustic alkaline taste, and changes vegetable blues to green. It attracts a certain portion of water with great force, evolving a quantity of caloric falling into powder, and becoming a dry hydrate; which is not decomposed by a red heat. This hydrate appears to consist of 1 atom baryta 78, + 1 of water 9; = 87. Like alkalies, it renders expressed oils miscible with water. It communicates a yellowish colour to the flame of alkohol.

It dissolves in boiling water; and the solution, as it cools slowly, deposits flattened hexagonal prismatic crystals; which on exposure to air effloresce, and fall into a white powder.

These crystals are soluble, at a boiling heat, in their own water. At 60° they dissolve in about 17 times their weight of water. Exposed to a continued heat, they swell, foam, and at length leave a dry powder, amounting to about 47 per cent. of the crystals.

According to Mr. Dalton's inference, the white powder consists of 1 atom baryta 78, + 5 of water 45; = 123, and the crystals of 1 atom baryta 78, + 20 atoms water 180; = 258.

Baryta attracts carbonic acid from the air, with great energy; and hence, if left exposed to the air, is soon converted wholly into a carbonate.

Baryta water is used as a test of carbonic acid. Carbonate of baryta being insoluble in water, or in small excess of carbonic acid.

A Peroxide of Barium may be formed, as Messrs.

Gay-Lussac and Thenard have shewn, by passing dried oxygen, slowly over the purest baryta; kept at a red heat, in a glass tube. It is a grey compound containing 1 atom barium 70, + 2 of oxygen 16; = 86. It was first used by the chemists above mentioned, to produce oxygenised water.

§ 3. *Chloride of Barium* is prepared by heating pure baryta in chlorine gas; the oxygen is disengaged, and the chlorine takes its place.

It may be obtained in abundance by dissolving carbonate of baryta in muriatic acid, evaporating the solution and igniting the mass.

It appears to consist of 1 atom of barium 70, + 1 atom of chlorine 36; = 106.

By solution in water, it is converted into a muriate of baryta; and then appears to consist of 1 atom baryta 78, + 1 muriatic acid 37; = 115.

It forms tabular crystals which are soluble in five parts of water at 60°. They are soluble in alkohol, and appear to consist of 1 atom muriate of baryta 115, + 2 atoms water 8; = 133, but it requires further examination.

§ 4. *Chlorate of Baryta* is procured by passing chlorine through a solution of baryta, until no more is absorbed. Phosphate of silver separates the chloride of baryta that is formed at the same time. The clear solution is then evaporated, when it produces quadrangular prismatic crystals, consisting of 1 atom of baryta 78, + 1 of chloric acid 76; = 154. This salt is used in the preparation of chloric acid.

Iodide of barium, iodate and hydriodate of baryta, may be formed. They are little known.

§ 5. *Nitrate of Baryta* is formed by dissolving the native carbonate in nitric acid, evaporating to dryness, redissolving, and crystallizing.

The dry salt consists of 1 atom of baryta 78, + 1 atom nitric acid 54; = 132, to which, add 2 atoms of water, 18; = 150, for the crystals. Its taste is acrid and astringent. It crystallizes in regular octædrons. They are soluble in

12 parts of water, at 60°, and in 4 at 212°. It is decomposed by a bright red heat.

It is used as a test for sulphuric acid.

It is the principal ingredient in the compound, used at the theatres for the production of green fire. The compound is as follows:—

Flowers of Sulphur . . .	13 parts
Nitrate of Baryta . . .	77
Chlorate of Potash . . .	5
Metallic Arsenic	2
Charcoal	1

All these ingredients must be thoroughly dried, and very intimately mixed.

§ 6. *Carbonate of Baryta* is readily formed artificially. It is also found native in several parts of England. Its primitive crystal is an obtuse rhomboid.

The native carbonate is more difficult to decompose by other acids, than the artificial.

Baryta attracts carbonic acid from all other bodies. Hence, carbonate of baryta is precipitated, when a solution of baryta is added to a solution of carbonate of potassa, soda, or ammonia.

It consists of 1 atom of baryta 78, + 1 atom of carbonic acid 22; = 100.

It requires about 4300 parts of water to dissolve it.

It is insipid, nor does it affect vegetable blues, nor reds. It is decomposed at a red heat, if any carbonaceous matter be present. For this purpose it should be finely powdered, and made into balls with water, and an equal bulk of flour. The ball should be placed in a crucible insulated with powdered charcoal, that it may not touch the sides, and then be exposed to the strongest heat of a wind furnace for, at least, two hours.

Carbonate of baryta is decomposed by sulphuric, nitric, and muriatic, and many other acids.

§ 7. *Proto-Sulphuret of Barium* may be obtained by cementation from sulphate of baryta, in the same manner as sulphuret of potassium, but the heat must be continued for a longer time. According to Mr. Berthier 120 parts of sulphate of baryta lose 34; or precisely the quantity of oxygen that the acid, and base of the sulphate contained. It is a light grey granular substance, which is soluble in water; during the solution, a part of the water is decomposed, and a hydrosulphuret of baryta formed: with muriatic acid, it affords a transparent solution, evolving sulphuretted hydrogen only. It is composed of barium 100, + sulphur 24.17.

Hyposulphite and sulphite of baryta, are easily formed by pursuing a process similar to that by which the corresponding salts of potash are obtained.

§ 8. *Sulphate of Baryta*, or heavy spar, is found native in several parts of Europe. In this kingdom it is found in Cumberland, Westmoreland, and Derbyshire, both massive, and in various crystallized forms. Its primitive crystal is a rhomboidal prism. Baryta and sulphuric acid have a very strong attraction for each other, and form a most insoluble salt, requiring 43000 times its weight of water to dissolve it. Hence they are the best known tests for each other.

Sulphate of baryta is soluble in concentrated sulphuric acid, but is separated again by the addition of water.

It consists of 1 atom baryta 78, + 1 sulphuric acid 40; = 118.

When heated, it decrepitates, and at length fuses into a white enamel.

When heated with $\frac{1}{8}$ of charcoal, it parts with its oxygen, and is converted into a sulphuret; from which the baryta is readily removed, by nitric, or muriatic acid.

If boiled with its equivalent weight of carbonate of potassa, $\frac{1}{3}$ part of it is decomposed; and a proportionate quan-

tity of carbonate of baryta formed. No more can be produced until this is removed.

If on the other hand equivalent proportions of carbonate of baryta, and sulphate of potassa are boiled together; it has been found that, of 85 parts of carbonate of baryta, 57 were converted into sulphate.

Sulphate of barytes is sometimes used as a pigment, under the name of permanent white. When powdered, and made into small sticks with mucilage, and exposed to a strong red heat for some time, it becomes strongly phosphorescent. Thus prepared, it is called the Bolognian phosphorus.

§ 10. *Borate of Baryta* is an insoluble compound.

Seleniate and biseleniate of baryta may be formed.

Fluate of baryta is prepared by dissolving fresh precipitated carbonate of baryta in excess of acid. It is nearly insoluble in water, or fluoric acid. It is abundantly soluble in muriatic acid.

Baryta and all its salts are violent poisons. The best antidote is the immediate exhibition of Glauber's salt.

The soluble salts of baryta are all precipitated by sulphuric acid, or any of its compounds. The precipitate is insoluble in nitric acid, and alkaline solutions. They are chiefly employed as tests of this acid.

Article 2. Strontium.

§ 1. Strontia, or rather the mineral containing it, called strontites, was first discovered about the year 1784, to be existing in a lead mine, in Argyleshire. Strontia has since been met with in other parts of Europe, in combination with sulphuric and carbonic acids.

Strontium is the metallic basis of this mineral. It very much resembles barium in appearance; and was obtained from the pure oxide, by Sir H. Davy, in nearly the same

manner, by means of voltaic electricity. It has not a very high lustre, appears fixed, difficult to fuse, and not volatile.

It rapidly combines with oxygen on exposure to air. When put into water, it decomposes it with violence, evolving hydrogen gas, and producing a solution of strontia. The atom of this metal is estimated at 44.

§ 2. *Strontia*, or pure oxide of strontium, may be obtained by decomposing the native sulphate or carbonate, in the manner directed for the decomposition of the sulphate or carbonate of baryta; the sulphuret obtained is dissolved in nitric acid, and the nitrate decomposed by strong ignition.

It appears to consist of 1 atom of strontium 44, + 1 atom of oxygen 8; = 52.

It is of a grey colour, and difficult to fuse. It eagerly absorbs water, producing great heat and falling into powder. The further addition of hot water dissolves it.

It crystallizes on cooling in small thin quadrangular plates, which more or less adhere together.

The hydrate appears to consist of dry oxide 52, + water 9; = 61.

The crystals when heated part with about 68 per cent. of water, and are supposed to consist of strontia 1 atom 52, + water 12 atoms 108; = 160.

The crystals dissolve in about half their weight of boiling water, or in 52 times their weight in water at 60° Fahrenheit.

It is not affected by the alkalies, nor by baryta. Alkohol in which they are dissolved, burns with a blood-red flame.

§ 3. *Chloride of Strontium* is produced by heating strontia in chlorine gas; the oxygen being disengaged. It may be produced by dissolving carbonate of strontia in muriatic acid, evaporating to dryness and heating it.

It consists of 1 atom of strontium 44, + 1 of chlorine 36; = 80.

By solution in water, it is decomposed and converted

into muriate of strontia, which, when dry, consists of strontia 52, + muriatic acid 37; = 89.

This muriate crystallizes in slender hexagonal prisms, which are deliquescent, and soluble in two parts of water at 60°. They are more soluble in alkohol, and communicate a red colour to its flame.

§ 4. *Chlorate of Strontia* is a deliquescent soluble salt, which detonates when thrown on hot coals; and communicates a beautiful purple light.

Iodide of strontium, iodate, and hydriodate of strontia may be formed; but are of no importance.

§ 5. *Nitrate of Strontia*, which may be produced by dissolving the carbonate in nitric acid, forms in octædral and dodecædral crystals; which are soluble in an equal weight of water at 60°.

The dry salt consists of 1 atom strontia 52, + 1 atom of acid 54; = 106.

Like the other saline compounds of this metal, it communicates a red colour to flame. It is decomposed at a red heat. It is used in preparing fire-works, and constitutes the principal ingredient in what is called red fire or flame. This is a compound of

Dry Nitrate of Strontia	40 parts
Sulphur	13
Chlorate of Potassa	5
Sulphuret of Antimony	4
Charcoal powdered	4

§ 6. *Carbonate of Strontia* may be prepared by passing carbonic acid slowly through a solution of strontia in water. It is found native also in several parts of the world; particularly at Strontian, in Scotland, where it was first discovered, and whence it was named. The native carbonate of strontia has a greenish tint.

It consists of strontia 1 atom 52, + carbonic acid 1 atom 22; = 74.

It is soluble in 1540 parts of water.

§ 7. *Sulphuret of Strontium* may be produced in the same manner as sulphuret of barium. Twenty parts of sulphate of strontia lost in converting them into a sulphuret 7.2.

It consists of strontium 100, sulphur 36, or strontium 1 atom 44, + sulphur 1 atom 16; = 60.

Hydrosulphuret, and hydrobisulphuret, may also readily be formed. The former affords crystals of a silky lustre.

Sulphite and hyposulphite of strontia may be produced. The latter is in crystals which are doubly refractive. When heated alone in a close vessel, they burn with a weak flame. They are soluble in twice their weight of water; and dissolve chloride of silver, forming a solution of an intensely sweet taste.

§ 8. *Sulphate of Strontia* has been found native in different parts of Europe. It sometimes has a blue tint, and hence it is called celestine. It is readily formed if necessary.

It consists of strontia 52, + sulphuric acid 40; = 92.

It requires 4000 parts of water to dissolve it. It may be converted into a sulphuret by charcoal. It is soluble in hot sulphuric acid, but separates on adding water.

§ 9. Phosphite, and hypophosphite of strontia, can be formed.

Phosphate of strontia is an insoluble salt, which is soluble in excess of phosphoric acid, and wholly decomposable by sulphuric.

Fluate of strontia is nearly insoluble in water.

Borate of strontia turns vegetable blues to green.

Seleniate of strontia is insoluble, and biseleniate nearly so.

In its chemical affections, strontia very much resembles baryta. They both attract a certain quantity of water with

great force, and retain it at a red heat. Both are crystallizable, but their crystals differ in form. Both form nearly insoluble sulphates and carbonates, and of both the native carbonates are most difficultly acted on by acids. Neither of them is precipitated by ammonia.

On the other hand, strontia and its compounds are not poisonous, as baryta and all its compounds are; excepting, *perhaps*, the sulphate on account of its insolubility.

The salts of baryta tinge flame yellow; those of strontia tinge it red.

Pure baryta is ten times more soluble in water than pure strontia. It has a stronger attraction for most acids than strontia has; and decomposes most of its combinations. The salts with base of baryta, are generally less soluble than those with base of strontia.

Article 3. Calcium.

§ 1. Calcium, or its oxide pure lime, in consequence of their strong attractions, have never been met with native; except in combination with other elements. But various mineral compounds that contain them, forming lofty mountains; and extensive strata exist in immense abundance in every known part of the world.

With carbonic acid, lime forms the numerous varieties of lime-stones, marble, chalk, and calcareous soils. It is found also, combined with most of the other acidifiable bases, earths, and oxides.

When the pure oxide is exposed to the voltaic agency in contact with mercury, an amalgam is at length obtained; from which the mercury may be separated by distillation in an hermetrically sealed tube, as in the preparation of barium.

It has the colour and lustre of silver. On exposure to

air, and gently heating it, it inflames, burns with a brilliant light, and produces lime.

From the experiments of M. Berzelius, 20 may be considered as the weight of its atom.

§ 2. *Lime* appears to consist of calcium 1 atom 20, + oxygen 1 atom 8; = 28.

White marble, when calcined for some hours in a heat gradually increased to a bright red, parts with its water and carbonic acid, and may be considered as very pure lime. Limestone is found to calcine better when a small circulation of air passes through the kiln.

Its specific gravity is 2.3. It is of a light grey colour. It is fusible by the oxyhydrogen blow-pipe, or in the voltaic circle; but it has not been volatilized.

Lime absorbs a certain quantity of water, with great force; producing heat and noise, falling into powder, and enlarging in bulk.

This dry hydrate consists of 1 atom lime 28, + 1 atom water 9; = 37.

This hydrate may be preserved in well-stopped glass bottles; but, when it is requisite to preserve it in large quantity, it is more economically mixed into a thick liquid, with water, and kept in a covered cask or cistern. In this state it is called cream of lime. It is not a definite compound of lime and water.

The quantity of heat evolved from lime in slaking it; that is, in converting it into a protohydrate, is, according to M. Dalton, about 800°. When the mass slaked is large, the ignition of combustible bodies has been produced, and houses set on fire by it. The heat thus evolved is supposed by some chemists to be evolved from the water, in consequence of its passing from a fluid state to a solid.

If ice be mixed with pure lime, in the proportion of one to two, they unite, producing a heat of 212°. Here the water is previously a solid.

If dry lime be left exposed to the air, it absorbs the hygrometric moisture; swelling in volume, and falling into powder, it becomes a protohydrate.

Lime is more soluble in cold water than in hot.

At 40°, it probably dissolves in 650 parts of water, producing a brilliant clear solution.

When this solution is evaporated in an exhausted receiver, by the agency of sulphuric acid, it at length deposits small transparent hexaedral crystals of protohydrate of lime.

If fresh lime be powdered, and made into a paste, with one-third of water, the paste soon loses its softness, and becomes a consistent solid mass, which gradually becomes harder.

If it be previously intimately mixed with a quantity of alumina or silica, or both, it sets more suddenly, and becomes still more firm.

This property of fresh made hydrate of lime, of crystallizing, or solidifying in combination with certain other earths, and of becoming harder, and more durable with them than without, is what renders it so valuable as a building cement.

For those cements which are intended to set quickly, or under water, those limestones are best which contain a certain quantity of silica and alumina in intimate mixture; but they require not to be overburnt. They must be finely powdered when fresh burnt, and kept from air and moisture until used.

The result of three analyses of Parker's Cement was, Lime 56—Alumina 8—Silex 24—Oxides of Iron and Manganese 12.—In some other examinations, the proportion of alumina was greater, and in others less.

Common mortar is always better in proportion as the lime is more freshly burnt, and more quickly used after being slaked. It is improved by being made with a por-

tion of powdered unslaked lime, and when well made, it is more durable the more slowly it dries.

The ultimate strength of common mortar, and its insolubility, depend upon its slow absorption of carbonic acid.

Lime powdered, and mixed with the serum of blood, is often used as a cement, and may be used as a permanent whitewash.

Lime, mixed with a fourth part, by weight, of iron filings and linseed oil, is sometimes used to stop the cracks in cast-iron.

Lime-water has a nauseous acrid taste, changes vegetable blues, and absorbs carbonic acid rapidly from the atmosphere; which separates the lime in the state of an insoluble carbonate. It unites with oil, forming an imperfect soap.

Peroxide of Calcium is produced by passing oxygen slowly through a tube, heated to a bright red, containing dry lime; and also, according to M. Thenard, by uniting it with oxygenized water.

§ 3. *Chloride of Calcium* may be produced, in the same manner as other chlorides, by heating dry lime in chlorine gas; when the lime parts with its oxygen, and the metallic base combines with the chlorine. Or it may be produced by evaporating and fusing muriate of lime.

It consists of calcium 1 atom 20, + chlorine 1 atom 36; = 56.

When fresh made, it is phosphorescent, and was formerly termed Homberg's phosphorus.

In this dry state, if powdered and mixed with water, considerable heat is evolved.

It is extremely deliquescent, and on uniting with water, is again converted into muriate of lime.

In this state it consists of muriatic acid 1 atom 37, + lime 1 atom 28; = 65; exclusive of water.

It, with some management, crystallizes in hexaedral

prisms, which are soluble in one-fourth of their weight of water, producing a great degree of cold. Its taste is bitter and nauseous.

It absorbs a considerable quantity of ammoniacal gas, producing an ammonio-muriate of lime.

The chief use of muriate of lime is in the production of cold, and in drying gasses. By mixing the crystals with fresh snow, a degree of cold may be produced, which is sufficient to freeze mercury.

If into a strong solution of muriate of lime, a proper quantity of sulphuric acid be poured, the consequent-precipitation will convert the whole into a solid mass.

§ 4. *Chloride of Lime*, or the usual bleaching powder of cotton and linen manufacturers, is prepared by passing chlorine slowly through protohydrate of lime, which has previously been sifted, until no more is absorbed. Some precaution is requisite to keep it cool, as considerable heat is evolved if the chlorine pass too rapidly; and in that case, a part of it becomes converted into chloride of calcium. Thus prepared, it is a white powder, which has an acrid taste, and a slight odour of chlorine.

When prepared with care, and decomposed by muriatic acid, Dr. Ure found 100 parts to consist of chlorine 40.31, lime 45.40, water 14.28. But when prepared in the usual manner, it seldom contains so large a proportion of chlorine.

When heat is applied to it, the water and the oxygen of the lime are expelled, and chloride of calcium formed.

When the powder is loaded with chlorine, a part of it is retained with so slight an attraction, that it escapes on the first application of heat, or combines with a part of the oxygen, forming chloric acid.

§ 5. *Chlorate of Lime* is a soluble deliquescent compound.

Iodide of calcium, iodate and hydriodate of lime, have not been used.

§ 6. *Nitrate of Lime* is obtained from nitre-beds with the alkaline nitrates, and is usually decomposed to procure nitrate of potassa. It may readily be prepared by dissolving carbonate of lime in diluted nitric acid.

The dry compound consists of 1 atom nitric acid 54 + 1 atom lime 28; = 82.

It crystallizes with difficulty, in hexaedral prisms; and the crystals appear to consist of 1 atom nitrate of lime 82, + 3 atoms of water 27; = 109.

It dissolves in its own water, when heated; the water at length evaporates, and on raising the heat the salt fuses, and on cooling forms a semi-transparent mass, which is phosphorescent, and is called Baldwin's phosphorus. For this purpose, after fusing it for about ten minutes, it should be poured upon a hot iron plate, broken up, and while yet warm, closely stopped in vials.

§ 7. *Carbonate of Lime* is perhaps the most abundant of natural minerals. It occurs crystallized in a variety of forms. The double refractive Iceland crystal is a beautiful specimen. Its primitive crystal is a rhomboid. It is found in primitive as well as in secondary strata of the earth. The former producing the most pure, perfect, durable, and beautiful marbles, free from any appearance of animal or vegetable matter. The carbonates of lime found in secondary strata are in great variety, and contain a surprising abundance of animal remains, mostly shells of fish, originally owing their substance and firmness to this compound chiefly. White marble is a very perfect specimen of pure carbonate of lime. It consists of carbonic acid 1 atom 22, + lime 1 atom 28; = 50.

Lime and carbonic acid, when both are perfectly dry, do not act on each other. If a portion of dry carbonic acid is confined over mercury, and a lump of dry lime be introduced, no absorption follows; but if it be confined over a mixture of lime and water, it is absorbed in a short time. When lime-water is exposed to the air, a film is shortly

perceived on its surface; it increases gradually in thickness, until its weight overcomes the cohesion of the fluid; then it falls down, and another film appears: this film is produced by the lime in the water absorbing carbonic acid, and becoming insoluble.

Carbonate of lime is decomposed at a bright red heat, and the acid evaporated. Pure marble in burning loses about 44 per cent.

By the application of a strong heat, while confined in a vessel strong enough to resist the elasticity of the gas, carbonate of lime may be fused undecomposed.

Mr. Bucholz has fused carbonate of lime by the sudden application of a strong heat without compression.

Carbonate of lime is decomposed by almost all acids, and the rapid escape of the acid through the liquid menstruum in the state of gas produces a violent effervescence, as is well known.

The extensive uses to which this body is applied are best comprehended by considering its physical properties, and its chemical, its abundance, and its capability of application to agricultural and architectural purposes.

It constitutes all the varieties of marbles that are known, and various other stones that are used in building; the Portland stone, for instance, and the Bath stone. The inferior limestones, marls, and chalks, occur in immense variety; and are extensively used in smelting, in agriculture; as well as in building, in the state of carbonate, or burnt into lime. The extensive use of chalk and whiting is well known. In chemistry, this compound is extensively used as a source of carbonic acid, as well as of lime.

Lime-water is a good test of the presence of carbonic acid in gasses or water.

Carbonate of lime is soluble in an excess of carbonic acid; the combination is retained but by a slight force. When exposed to the atmosphere, the acid escapes, and the neutral carbonate is deposited. In this way are formed the

various stalactites, stalagmites, and tufas of carbonate of lime, so frequently met with native in caverns and elsewhere.

§ 8. *Sulphuret of Calcium* may be procured by cementation with charcoal, from sulphate of lime. It requires, according to M. Berthier, a white heat for two hours. When the operation is ended, it retains the form and appearance of the sulphate employed. 20 parts of the native gypsum treated in this way lost 9.24. The sulphuret contained, calcium 100, + sulphur 78.3. Like the other protosulphurets, it is soluble in water without any decomposition, except of a portion of water so as to produce a hydrosulphuret of lime; and it dissolves in muriatic acid, evolving sulphuretted hydrogen only.

A mixture called sulphuret of lime, is formed by fusing one part of sulphur with two or three parts of lime. It is decomposed by the addition of water. It is sometimes used as a test of oxygen, which it absorbs.

§ 9. *Hydrosulphuret of Lime* is formed by passing sulphuretted hydrogen through water in which lime is suspended. Colourless crystals are produced, which are readily soluble in water.

§ 10. *Hydrogenetted Sulphuret of Lime*, or hydrobisulphuret, Mr. Herschel obtained by boiling 3 parts hydrate of lime, 1 sulphur, and 20 of water: on allowing the solution to cool, he obtained crystals, which he dried by sulphuric acid under an exhausted receiver. They had the form of four-sided prisms; they dissolved sparingly in cold water, had an acrid sulphurous taste, and a yellowish colour. They consisted of lime 2 atoms, sulphur 2 atoms, hydrogen 1 atom, water 4 atoms.

§ 11. *Hyposulphite of Lime* is produced by passing sulphurous acid gas through a solution of the last mentioned salt. If evaporated quietly to a certain point, filtered, and then further evaporated, at a temperature below 140°; it yields, on cooling, large beautiful crystals affecting various

complicated forms. They consist of hyposulphurous acid 2 atoms, lime 1 atom, water 6 atoms, according to Mr. Herschel.

Sulphite of lime crystallizes in six-sided prisms, is very insoluble, and passes into a sulphate.

§ 12. *Sulphate of Lime* exists in great abundance in different parts of the earth, in the states of alabaster, selenite gypsum or plaster of Paris. Its crystal, when pure, is a transparent rhomboidal prism. It is softer than carbonate of lime.

It consists of lime 1 atom 28, + sulphuric acid 1 atom 40; = 68. It is easily produced artificially. It is soluble in about 350 parts of water, and by slow evaporation produces silky crystals. These crystals are composed of dry salt 1 atom 68, + water 2 atoms 18; = 86. At a red heat it parts with its water, and fuses on the temperature being raised.

Native sulphate of lime, free from water, is occasionally met with.

It is decomposed by alkaline carbonates and by charcoal at a high temperature.

In consequence of its general dispersion, and of its degree of solubility, it is very frequently found dissolved in spring waters, which are employed for domestic purposes. It renders these waters hard; they decompose and curdle soap, and have a peculiar earthy flavour.

A small addition of an alkaline carbonate precipitates the lime in the state of chalk; and if a slight excess be added, it improves such water, both for washing, and for boiling green vegetables.

When it has been deprived of its water, at a low red heat, and is mixed into a paste with water, in a few minutes a partial sudden crystallization takes place, some heat is evolved, and it becomes solid. During this solidification, it expands a little. It is extremely well adapted, there-

fore, for taking casts, a use to which it is very extensively applied. It is much used in making plaster ornaments, as a cement, and for moulds in potteries. It is too soluble in water to bear the weather.

§ 13. *Phosphuret of Calcium*, called phosphuret of lime, may be formed by introducing into a porcelain or coated green glass tube, 12 or 16 inches long, and one-third of an inch in diameter, closed at one end, about a quarter of an ounce of phosphorus, and then filling the tube with small bits of pure lime. Slightly stop the orifice, and place the tube obliquely in a furnace, so that the lime may become of a red heat, while the lower end of the tube is cool. Then draw into the fire the lower part of the tube, that the phosphorus may be gradually heated. An union will take place, and a reddish brown compound be produced.

It decomposes water at the temperature of the atmosphere. If a bit of it be dropped into a basin of water, bubbles of phosphuretted hydrogen gas rise to the surface, inflame, and explode.

When into a deep glass full of water, furnished with a tube which reaches to the bottom, a bit of phosphuret of calcium, and half as much chlorate of potassa, are dropped; on pouring into the tube some concentrated sulphuric acid, the chlorate of potash, the phosphuret of calcium, and a portion of water, are all decomposed together; and while fire is seen darting from the surface of the water, the bottom is illuminated by a beautiful green light.

Phosphite and hypophosphite of lime may be obtained.

§ 14. *Phosphate of Lime* is found native; but its chief source is animated nature. It constitutes the principal part of the bones of all quadrupeds, and of man.

The pure phosphate of lime may be obtained by calcining the bones, powdering and dissolving the phosphate in muriatic acid, and precipitating by ammonia.

It may be obtained from the bones though slowly with-

out destroying their animal structure. When muriatic acid, diluted with about thirty parts of water is poured upon fresh bone, it will at length remove all the phosphate of lime, and leave the bone like a tough flexible tendon.

Phosphate of lime consists of phosphoric acid 1 atom 28, + lime 1 atom 28; = 56.

It is insoluble in water, but soluble in nitric, muriatic, and sulphuric acids; and fuses into a milky enamel.

It is used in various arts, sometimes in potteries, and is the usual source whence chemists obtain phosphorus and phosphoric acid.

§ 15. *Biphosphate of Lime* is formed by the addition of an equivalent proportion of phosphoric acid.

A triphosphate of lime may be formed also. According to Dr. Thompson the fused phosphoric acid called phosphoric glass, prepared by the decomposition of bone, and known to contain a portion of lime, is a quadriphosphate. Mr. Dalton thinks the phosphoric glass to be an octophosphate, and that a phosphate may perhaps be obtained of 12 atoms of acid to 1 atom of lime.

A beautiful crystallized variety of phosphate of lime is found in Devon and Cornwall; which is supposed to be a subphosphate, consisting of 2 atoms of lime to 1 of phosphoric acid.

Borate of lime is an insipid almost insoluble powder.

Selenic acid is capable of affording a seleniate and a biseleniate of lime.

§ 16. *Fluate of Lime* is precipitated, whenever hydrated fluoric acid is poured into a solution of a salt with base of lime. A similar compound is found native, in different parts of the world; in particular, a very beautiful variety is found in Derbyshire, and well known by the name of Derbyshire spar.

It is usually met with in small masses from an inch to a foot in thickness.

It is by the decomposition of this mineral, with sulphuric acid, that fluoric acid is produced; but as this acid has never been so decomposed, that its base may be obtained in a pure state, it cannot be considered to have been analyzed. A doubt, therefore, is thrown over the true nature of all its combinations.

From analogy, some chemists think that Derbyshire spar is a compound of the base of fluoric acid, with the base of lime; and is in fact a fluoride of calcium:—that, as in the case of muriatic acid, the acid is a *hydro-fluoric* acid, and when it is combined with lime, a hydrofluate of lime is formed. That upon heat being added, a double decomposition is produced, the oxygen leaving the lime, to combine with the hydrogen of the acid; thus water is produced, and fluoride of calcium formed. Others think that fluoric acid contains oxygen, and that this mineral is a fluate of lime.

The salts with lime for their base are many of them insoluble. Those which are soluble, produce an insoluble precipitate with oxalates of ammonia, potassa, and soda; and also with the carbonates of these three alkalies, but not with caustic ammonia. The insoluble salts, when boiled with a solution of carbonate of potash, produce carbonate of lime.

Article 4. Magnesium.

§ 1. This chemical element exists in considerable abundance in the state of carbonate of the oxide, contributing to the formation of various earthy minerals; some of which are in extensive strata, forming magnesian lime stones, dolomite, serpentine, &c. An hydrate of pure magnesia has been found in New Jersey. The purest of the magnesian minerals are smooth, and greasy to the touch; generally opaque, of a greenish tint, and more or less flexible, as

are the soap-stones, asbestos, talc. It is an ingredient also in sea water.

The metal magnesium was produced with great difficulty and very imperfectly by Sir H. Davy, during his celebrated experiments on the alkalies and earths with the voltaic battery at the Royal Institution in 1807, by a process similar to that by which barium was produced, but a much longer time was required to produce an amalgam.

No further experiments on this subject of any importance have been published since.

"I succeeded," says he, "in decomposing magnesia "likewise, in the following manner. I passed potassium "in vapour, through magnesia heated to intense whiteness, "in a tube of platinum out of contact of air. I then intro- "duced a small quantity of mercury, and heated it gently "for some time in the tube. An amalgam was obtained "which by distillation, out of the contact of the atmo- "sphere, afforded a dark grey metallic film, which was "infusible, at the point at which plate-glass softened; and "which in the process of distillation with mercury ren- "dered the glass black at its point of contact with it. "This film burnt when heated strongly, with a red light; "and became converted into a white powder, which had "the characters of magnesia. When a portion of the "metal was thrown into water, it sunk to the bottom and "effervesced slowly, becoming covered with a white pow- "der. By adding a little muriatic acid to the water, the "effervescence was violent, the metal rapidly disappeared, "and the solution was found to contain magnesia."

The attempt was repeated, but, as the heat was increased, the potassium acted so powerfully on the platinum, as to prevent further success than that of confirming the conjecture, that oxygen passed from the magnesia to the potassium.

From calculation, the equivalent of an atom of magne-

sium may be considered as 12. Its oxide, or pure magnesia then may be stated at magnesium 1 atom 12, + oxygen 1 atom 8; = 20.

§ 2. *Magnesia* may be obtained by calcining the pure carbonate in a bright red heat for some time. Its specific gravity is about 2.3.

It may be considered as the last in gradation of the alkaline earths, the peculiarities of which it resembles in several respects.

It is an insipid and inodorous white powder, it is insoluble, and infusible, except in a very intense heat. But it is perfectly fusible in the heat of the oxy-hydrogen blowpipe.

It has an affinity for water; and attracts a portion of the hygrometric water from the atmosphere, but no apparent heat is excited by their mixture. When separated by a superior affinity from its combinations, it is in the state of a hydrate; when dried in the heat of boiling water it still retains nearly about one-sixth of water. When precipitated by pure potassa, and soda, and dried at a very low heat; it is in the state of a soft semitransparent brittle mass, containing about one-fourth of water. According to M. Berzelius 100 of magnesia combines with 44 of water.

But different chemists have obtained different results. The attractions between magnesia and water are comparatively slight; and they do not appear to produce any marked definite compound that can, with certainty, be ascertained. A native hydrate of magnesia, when analyzed, produced 69.75 base and 30.25 water in 100 parts. This is a near approximation to a protohydrate of magnesia.

Magnesia reddens turmeric, and turns vegetable blues green; but its action is so feeble in this respect, that some chemists attribute its effects to a portion of adhering lime, which it is very difficult to separate.

It is not acted on by liquid alkali.

The use of pure magnesia is chiefly confined to medicine.

§ 3. *Chloride of Magnesium* may be produced by decomposing the muriate at a dull red heat. It consists of magnesium 1 atom 12, + chlorine 1 atom 36; = 48.

By the addition of water this is re-converted into a muriate consisting of magnesia 1 atom 20, + muriatic acid 1 atom 37; = 57.

This is a bitter tasted, soluble, deliquescent salt; decomposable by a bright red heat, and soluble in alkohol.

A compound which may be called chloride of magnesia is produced by passing chlorine, slowly over cold hydrate of magnesia. Its chemical nature and properties are similar to the chloride of hydrate of lime. It is used occasionally for bleaching. It crystallizes in rhombs.

A muriate of potassa and magnesia, may be formed; but the combination is retained by an attraction so slight that water alone destroys it. Alkohol dissolves the magnesian muriate, leaving the muriate of potassa.

§ 4. *Chlorate of Magnesia* may be produced. So may also iodide and subiodide of magnesium, and iodate and hydriodate of magnesia, but their properties have not been examined.

§ 5. *Nitrate of Magnesia* may be crystallized in rhomboidal prisms which are deliquescent, and consequently very soluble.

It consists of 1 atom acid 54, + 1 atom of magnesia 20; = 74.

Its taste is bitter and cooling. It is decomposed at a red heat.

An ammonio nitrate of magnesia may be obtained in prismatic crystals, soluble in about 11 parts of water.

§ 6. *Carbonate of Magnesia* is sometimes found native.

In commerce it is generally produced by the decomposition of sulphate of magnesia, by an alkaline carbonate.

It consists of carbonic acid 1 atom 22, + magnesia 1 atom 20; = 42 with 1 atom water 9; = 51.

It is a white powder insipid, and insoluble. It is decomposed at a red heat.

If carbonate of magnesia be diffused through water through which carbonic acid is slowly passing, a part of it is dissolved. If decanted and set aside, it will slowly deposit crystals, which are slightly adherent to the sides of the vessel, sometimes extending like small radii from a center. When exposed to the air they are slightly efflorescent.

They were supposed to consist of a bicarbonate; but the analyses of Dr. Henry and M. Berzelius, show them to be a carbonate, consisting of carbonic acid 1 atom 22, magnesia 1 atom 20, + water 3 atoms 27; = 69. So that the agency of the free carbonic acid, is merely to render the carbonate soluble in the water; and by its slow evaporation to favour the free operation of the attraction of cohesion.

It may be considered as insoluble, for it is said to require for solution 9000 parts of boiling water, which again deposits two-thirds on cooling to 60°.

The attraction of magnesia for carbonic acid is slight, compared with that of the alkalies, and other alkaline earths. Its carbonate is decomposed by lime water.

A carbonate of magnesia and potassa is spoken of by M. Berzelius, as forming crystalline groups, in a mixture of carbonate of potash and muriate of magnesia; which when separated consisted of potassa 18.28, magnesia 15.99, carbonic acid 34.49, and water 31.24 in 100 parts.

§ 7. A *Sulphuret of Magnesia* may be formed. Hydrosulphuret of magnesia may also be formed, but it has not been examined.

A hyposulphite and sulphite may be formed: the latter is

insoluble, until an excess of acid be added. As the acid slowly evaporates, it crystallizes. Its crystals are soluble in about twenty parts of water at 60°.

§ 8. *Sulphate of Magnesia* is frequently found native. It is prepared by decomposing the muriate of magnesia present in sea water; and left in the liquor after the precipitation of sea salt, and also by the decomposition of magnesian lime-stones. It crystallizes in small four-sided prisms with diedral summits.

It consists of sulphuric acid 1 atom 40, + magnesia 1 atom 20, + water 7 atoms 63; = 123.

This salt is well known as Epsom salt. It is slightly efflorescent in dry weather. It is soluble in an equal weight of cold water, and the solution has a saline and bitter taste. It is not precipitated by carbonate of ammonia.

If pure ammonia be added to a solution of the sulphate of magnesia, it precipitates a part of the magnesia; and combining with the remainder of the compound, forms a double salt, a sulphate of magnesia and ammonia, containing in 100 parts, 68 of sulphate of magnesia, and 32 of sulphate of ammonia.

It forms double salts with potassa and soda also.

§ 9. Magnesia, with phosphoric acid, forms a phosphate and a biphosphate of magnesia; having no particular properties.

An ammonio-phosphate of magnesia readily forms. It is a white nearly insoluble powder. This salt is produced when phosphate of soda is added with ammonia as a test of magnesia, or to separate it from some of its other combinations.

§ 10. Fluate of magnesia is insoluble.

Borate of magnesia is met with native. The primitive form of its crystal is a cube. It is electric.

Selenic acid forms a seleniate, and a biseleniate of magnesia.

Most of the magnesian salts are soluble in water, and are

precipitated by pure soda, or by its carbonate. Phosphate of soda does not immdediately affect magnesian salts; but upon the addition of a little ammonia, a white precipitate of ammonio-phosphate of magnesia falls.

Section IV. *Of the Metals that produce the Oxides usually called Simple Earths.*

Two of the bodies included in this division occur, combined with oxygen in great abundance; constituting two of the most general and useful of the primary earths, that contribute largely to the bulk of our globe. The other four have been met with in very inconsiderable quantities.

Article 1. Aluminum.

§ 1. *Aluminum* is the basis of an earth which occurs in immense abundance. It is the basis of all sorts of clays, boles, and slates, in which it is generally mixed with silica, and forms a large proportion of all loams. It is an ingredient in granite, and in various minerals. It is the substance to which, in union with water, they owe their peculiar plastic properties. Some of the minerals containing it, have a certain adhesiveness when applied to the tongue; and a peculiar smell when breathed upon.

In the dry state, it constitutes the basis of some of the hardest and most beautiful minerals, such as the sapphire, the oriental topaz, and the ruby.

Wavelite is an hydrate of pure alumina decomposable by a strong red heat.

Aluminum has not been produced in the pure state. Nothing, therefore, can be known of its physical properties.

It is capable, according to M. Berzelius, of being combined under the voltaic influence with fused iron, into an alloy; which slowly effervesces in water, becoming covered

with a white powder which is alumina. Alumina communicates oxygen to potassium also, but the products have not been satisfactorily examined.

§ 2. *Pure Alumina* may be obtained by exposing that kind of alum, which is a sulphate of alumina and ammonia, to a gentle heat gradually raised to a bright red.

Or by dissolving common alum in twenty parts of water, and adding a little solution of carbonate of soda, to remove any iron that may be present. The liquid thus purified is then to be added slowly to liquid ammonia, but leaving the ammonia in excess. A spongy white precipitate falls down, which, when dried at atmospheric temperature, retains nearly half its weight of water.

Alumina, when artificially prepared, is a white soft powder. It is capable of forming, with water, a remarkably smooth adhesive ductile paste; which retains a certain quantity of water with considerable force, and may readily be turned in a lathe.

It is tasteless, inodorous, and does not change vegetable colours. It is infusible, except by the oxyhydrogen blowpipe. Its specific gravity is 2.

It is soluble in solutions of potassa, soda, baryta, and strontia, and also combines with them by heat, or fusion; and with most of the earthy and alkaline bodies, into very hard durable compounds which are called porcelaineous. With silica it forms porcelain.

It has, when fresh precipitated from watery saline solutions, a strong affinity for various animal and vegetable colouring matters.

When exposed to heat it gradually contracts in volume, in a certain degree proportionate to the heat applied, and the time of its application. Upon this property was Mr. Wedgewood's pyrometer founded; but the contraction of clay is not steady, nor sufficiently uniform for such a standard.

During the exposure to heat, it loses its water, and becomes very hard, insoluble in water, and at length even in acids. It may then be restored to its former state by fusion with an alkali; and dissolving the fused mass in muriatic, or any other acid, and precipitating the alumina again by ammonia.

The equivalent of alumina is very differently estimated by different chemists. The subject requires further investigation. Its atom may perhaps be estimated at aluminum 10, + oxygen 8; = 18.

This earth contributes, very extensively, to the use and comfort of mankind.

It is a chief ingredient in many soils, and in all the loams used in agriculture.

Its power of retaining water, and communicating a degree of plasticity, renders it a valuable addition to all porous, sandy, loose soils.

The same plastic property, and that of combining with silica at a red heat, renders it a valuable ingredient in bricks, tiles, earthen and stone ware, and fine pottery of all kinds. It is the basis of the finest porcelain. When mixed with a due proportion of silex, to counteract its shrinking, and cracking, it forms the most durable figures and statues.

In consequence of its extreme insolubility in caloric, with a small proportion of silica, it forms the most refractory furnaces, and crucibles of the chemist, and pyrotechnic artist.

§ 3. Alumina has little or no attraction for chlorine. With muriatic acid in excess, it forms a deliquescent jelly, from which the acid escapes, when a strong heat is applied.

A chloride of alumina formed by the same process as chloride of lime, has been recommended for discharging the Turkey-red dye, as a preparation which does not injure the cloth, nor annoy the workmen.

§ 4. *Nitrate of Alumina* is a soluble deliquescent salt, decomposable by heat.

Carbonic acid has a very slight attraction for alumina.

§ 5. Sulphuret of alumina may be produced as the preceding sulphurets are.

Sulphate of alumina will not crystallize. It is used as a test for potash, with which it combines, producing crystals of alum.

§ 6. *Alum*, a salt well known, and extensively used, is a double salt, a bisulphate of alumina and potassa, having very distinct characters. It forms in octoedral crystals.

It is usually obtained by roasting, and washing certain clays, containing pyrites, and adding a carbonate, or sulphate of potassa.

According to the analysis of Dr. Thomson, it consists of, potassa 1 atom 48, alumina 3 atoms 54, sulphuric acid 4 atoms 160, water 25, atoms 225; = 487.

Its specific gravity is 1.71. It has an astringent taste, rather sweet and peculiar. It is soluble in five parts of water, at 60°, and $1\frac{1}{2}$ at 212°. It turns vegetable blues to red. It effervesces with carbonate of potassa, a certain quantity of which produces no precipitate; but, when the excess of acid is saturated, a further addition precipitates the alumina with a portion of acid.

When exposed to a gentle heat it melts, bubbles, and swells up, while the water is escaping; and becomes, at length, a dry spongy mass. A certain portion of the acid gradually escapes as the heat is elevated.

An alum sometimes occurs in commerce in which ammonia, instead of potassa, is joined with the alumina. An alum may be made, it is said, with soda also.

Alum mixed with flour, and calcined for some time, produces Homberg's phosphorus.

Alum is used extensively in dying, for opening the pores of the fabric, attracting and fixing the colours; for alumina,

as it is separated from its saline compounds, while yet in a gelatinous state, has the property of attracting and combining with the colouring matter of most vegetable and animal substances.

A concentrated solution of it preserves perishable animal and vegetable matters from putrefaction.

It is the basis which holds the colours in crayons, lakes, &c. It is used in copper-plate, and in calico-printing. Wood soaked in alum is rendered less combustible, and so is paper. It is used extensively by bakers, to give to bread its saleable whiteness. It is used also in tanning, and in various other manufactories.

Different substances are covered by way of ornament, with crystals of alum, variously coloured. If the substance have a smooth surface, it must be covered with worsted, or some rough body which will dispose the liquor to crystallize upon it. By adding muriate of iron to the solution a yellow colour is produced; blue is produced by Saxon blue; pale blue by an equal part of sulphate of copper; crimson and red by cochineal and madder; black by sulphate of iron, and infusion of galls; green by sulphate of copper and muriate of iron; white by the vapour of ammonia.

The other salts of alumina have not been applied to any use.

Fluate of alumina is very soluble in water.

Article 2. Glucinum.

§ 1. Glucinum is probably a metallic substance. The only account published, relative to its nature, is by Sir H. Davy, who says, "The evidence that it is such, I have obtained by heating glucina with potassium in the same manner as alumina; the potassium was for the most part converted into potassa; and dark-coloured particles, having a metallic appearance, were found diffused through the mass,

which regained the earthy character, by being heated in the air; and by the action of water; in the last case, hydrogen was slowly disengaged."

§ 2. *Glucina* was discovered near the end of the last century, by M. Vauquelin, in the beryl, a hard gem found in Siberia. It has also been detected in the Peruvian emerald.

It is considered as consisting of glucinum 1 atom 20, + oxygen 1 atom 8; = 28.

Its specific gravity is 2.97.

It dissolves in potassa and soda, not in ammonia: it dissolves however in carbonate of ammonia.

It is rather adhesive, like alumina, and ductile, but not soluble in water. It does not change vegetable reds nor blues. It does not harden and contract by heat. It is infusible. It appears to have an attraction for colouring matter.

It combines with various acids. Its compounds have a sweet astringent taste; whence it has its name from glucus, sweet.

Article 3. Ittrium.

§ 1. "When ittria," says Sir H. Davy, who alone has investigated this subject, "is heated with potassium in the same manner as the other earths, similar results are obtained. The potassium becomes potassa, and the earth gains appearances of metallization, so that it is scarcely to be doubted that ittria consists of inflammable matter, metallic in its nature, combined with oxygen."

§ 2. Ittria was discovered near the end of last century by M. Gadolin, in a stone from Itterby, in Sweden.

It is supposed to consist of ittrium 1 atom 30, + oxygen 1 atom 8; = 38.

Its specific gravity is 4.84.

It is an insipid white powder, which does not act on vegetable colours. It is insoluble in water, but retains it with force. It is soft, and smooth to the touch; and requires an intense heat to fuse it. It is not acted on by the alkalies. It is soluble in carbonate of ammonia.

It is soluble in most acids, producing salts of a sweetish austere taste, and is precipitated from them by the alkalies, baryta, and lime.

Article 4. Thorinum.

Thorinum has been arranged among the metals by analogy. It has not been examined by voltaic electricity.

In the year 1815, professor Berzelius met with a new earthy substance, in small quantity, in combination with native fluates of cerium and yttria. This earth he considered to be undoubtedly a metallic oxide, and named it thorina.

When rendered pure, it is perfectly white. It absorbs carbonic acid, and dissolves with effervescence in acids. It is rendered less easily soluble by calcination.

The solutions of its neutral salts have a pure astringent taste, in which property it agrees with zirconia only.

Dissolved in a slight excess of sulphuric acid, it yields on evaporation, transparent crystals, which are permanent, and have a sweet astringent taste.

It is not soluble in pure alkalies. It is precipitated by the alkaline carbonates, absorbing the whole of their acid. It is precipitated by oxalate, tartrate, and benzoate of ammonia. It is not acted on by charcoal, nor is it fusible before the blow-pipe; but it may be fused into a transparent glass with borax or phosphate of soda.

Article 5. Zirconium.

§ 1. Zirconium, the supposed metallic base of zircon, may be obtained, according to Berzelius, in a manner similar to that used for the production of silicum; which will be presently spoken of.

It is as black as carbon, does not oxydate in water, nor in muriatic acid. Nitromuriatic acid dissolves it feebly, sulphuric and fluoric acids readily, the latter with the evolution of hydrogen.

When the temperature is slightly elevated, it burns with great intensity. Heated below redness, it burns in chlorine. It produces a chesnut-brown sulphuret, insoluble in alkalies, or muriatic acid, but which burns with brilliancy, producing sulphurous acid and zirconia.

§ 2. *Zirconia* is an earth, which was discovered in the year 1789 by M. Klaproth, in the jarcon of Ceylon, and has since been found in the hyacinth.

When pure, it is an insipid white powder, which is rather harsh, like silica. Its specific gravity is about 4.

It consists, according to Sir H. Davy's estimation, of zirconia 1 atom 35, + oxygen 1 atom 8; = 43. It is devoid of taste and smell.

It is insoluble in water, but when slowly dried after precipitation, it retains about one-third of its weight of water, assuming a slightly transparent yellowish colour, resembling gum arabic.

It is insoluble in alkalies, either by fusion or by solution; but it is soluble in alkaline carbonates.

When exposed to a strong heat it fuses, becomes of a light grey colour, and so hard as to strike fire with steel, to scratch rock crystal, and to become insoluble.

When fresh precipitated, and slowly dried, it dissolves

readily in acids, producing compounds which are nearly insoluble, and do not appear to crystallize easily.

Professor Pfaff has remarked the striking resemblance between zirconia and an oxide of titanium.

Article 6. Silicum.

§ 1. Silicum is the base which, when combined with oxygen, produces silica.

Berzelius (Ann. de Chimie) says, that nothing is easier than to procure pure silicum by the following process.

Fluate of silica and potassa, or soda powdered, and heated to redness, to drive off hygrometric water, is to be introduced into a glass cylindrical retort; pieces of potassium are then to be introduced and well mixed with it, by heating it until it fuses, and lightly shaking the tube. The heat is then to be raised by a lamp. Before it arrives at a red heat there is a slight detonation, and the silicum is reduced. The mass, when cooled, is to be washed with water. A small portion of silicuret of potassium that forms, is decomposed; and hence there is some hydrogen disengaged.

The substance thus produced, is a hydruret of silicum. At a red heat, it burns vividly in oxygen. When heated in a covered platinum crucible, slowly augmenting the fire to redness, the hydrogen only becomes oxidized. The silicum will now no longer burn in oxygen. A little silica is produced, which may be removed by fluoric acid. It is a white ductile metal, having a specific gravity about 7.

Pure silicum is incombustible in air, or oxygen gas. It is not acted upon by water, nitric acid, nor by nitromuriatic acid, nor by pure potassa. Fluoric acid dissolves a little of it, especially if nitric acid be added. At a very intense heat it decomposes nitre. At a dull red heat it decomposes

carbonate of potassa, carbon, and carbonic oxide being produced. When heated with nitre, the introduction of a small piece of dry carbonate of soda, causes an immediate detonation. If the vapour of sulphur be passed over silicum at an elevated temperature, the metal becomes incandescent. When the combination is perfect, which rarely happens, a white earthy substance is produced, which rapidly decomposes water, sulphuretted hydrogen being liberated. Thus a solution of silica in water may be obtained, so concentrated, that during evaporation, it thickens, coagulates, and deposits part of the earth, in the state of a transparent gelatinous mass.

Silicuret of potassium, heated with sulphur, burns vividly; and the product, on the addition of water, leaves pure silicum.

Silicum takes fire in chlorine at a red heat, and produces a liquid, which is colourless, or of a pale yellow, very volatile, and from which water separates gelatinous silica.

M. Berzelius obtained an alloy of iron and silicum, by heating together 6 parts of iron, 3 of silica, and 1 of charcoal, in a powerful blast furnace.

This investigation has been pursued by Stromeyer, who has produced alloys in different proportions, and recommends 7 of iron, 5 of silica, and ½ of soot, as the best.

In its nascent state it appears to combine with several of the metals.

In some respects its compounds with oxygen may be considered as analogous to acids, as has been observed by M. Berzelius; but in its more general properties and combinations, its oxide may rather be considered to be one of the most perfect earths.

§ 2. *Silica*, or oxide of silicum, is one of the most abundant bodies in nature. Rock crystal may be considered as pure native silica. It occurs in six-sided prisms, terminated by six-sided pyramids.

It is nearly infusible, so hard as to strik[illegible] and has a specific gravity of 2.6.

According to M. Berzelius, it consists of [illegible] oxygen 52.

It forms the principal part of all quartz, flints, ch[illegible] dony, gravel, sand, and granite; and is a very extens[illegible] ingredient in numerous rocks, mountains, and soils, combined with alumina, with lime, with magnesia, and occasionally with baryta, soda, potassa, and other bodies.

To obtain pure silica, take some common flint stones, expose them to a red heat, and throw them into cold water. Repeat this, and they will be disintegrated, and easily reduced to a fine powder.

Mix one part of this powder with four of carbonate of pot[illegible] assa, in a large crucible, and gradually raise it to a r[illegible] heat, stirring, and pressing it down, as it swells up. W[illegible] the effervescence has ceased, keep the mass in fusion [illegible] about half an hour, and pour it out on an iron plate. [illegible] solve it in water, filter or decant the solution, and add [illegible] it muriatic acid in excess, evaporate to dryness, and [illegible] ith boiling distilled water wash away the muriate of potassa. The silica not being soluble in muriatic acid, is left in the state of white powder; but it will contain a minute portion of potassa, and may contain alumine. Boil it, therefore, in a small quantity of sulphuric acid, and add a little sulphate of potassa; then wash it again repeatedly.

Silica thus prepared feels dry and harsh between the fingers. When fresh and dried in the atmosphere, it retains about 26 per cent. of water, which it parts with on being heated. A native hydrate of silica is met with in the opal. The different opals containing from five to ten per cent. of water.

When recently precipitated, it forms a jelly with a part of the water.

When the solution of silicate of potassa is largely diluted with water, and the potassa neutralized, no precipitate falls

down for a length of time; the silica remaining suspended, and apparently dissolved in the water. At length, however, a transparent jelly precipitates.

When dried, it is wholly insoluble. It is insoluble in all acids, except the fluoric, unless, indeed, when fresh prepared, for then it is *said* to be sparingly soluble in some acids.

It combines readily by fusion with the alkalies, and alkaline earths, and perhaps too with all other oxides, which are not too readily decomposed by heat, into vitreous compounds. It is, therefore, considered by some chemists as being an acid.

When combined by fusion with an alkali in excess, it forms double salts with several acids; but it is precipitated, in a gelatinous state, by hot water.

When an alkaline solution of silica has been set aside for some years, crystals of silica have been found, hard enough to scratch glass.

Chlorine and iodine do not appear to act upon silica.

§ 3. With fluoric acid it combines, producing a peculiar gas called *fluosilicic acid*. To obtain it, three parts of fluor spar are to be mixed with one part of flint, both in fine powder, put into a retort with three parts of sulphuric acid, and a gentle heat applied. The gas may be received over mercury in glass vessels.

It is a colourless gas, very acrid and sour. It somewhat resembles muriatic gas in its effect upon the lungs. Its specific gravity, compared to common air, is 3.57. It produces white fumes on escaping into the air, in consequence of its combining with the hygrometric moisture and depositing silica. It is partially decomposed, a quantity of silica being separated, by combining it with water, which absorbs 263 volumes of the gas. This solution may be kept in glass vessels without acting on them.

M. Berzelius calls the gaseous fluosilicic acid, a fluate of

silica, and says, that 100 parts of fluoric acid are combined with 144.6 of silica; and that these proportions of acid and silica contain equal quantities of oxygen. When the gas combines with water, it loses one-third of silica, and thus forms hydrated fluosilicic acid.

It combines with most of the alkaline or oxide bases, a similar change taking place, constituting a class of double salts called silicated fluates; the silica in these cases forming, according to M. Berzelius, a part, not of the acid, but of the base.

This gas unites with twice its volume of ammoniacal gas, and the mixture is wholly condensed into a dry white salt, which is slightly acid, and is a fluate of silica and ammonia. When dissolved in water, it slowly lets fall silica, and then, if its concentrated solution be boiled in glass vessels, it acts upon them. By an addition of liquid ammonia, the whole of the silica is precipitated, and a pure fluate of ammonia produced.

Potassium heated in this gas burns, producing a brown compound, which, when dissolved in water, becomes a hydrated fluate of potassa.

§ 4. The uses of silica, and of the compounds containing it, are very extensive.

In combination with alumina, it is the basis of all our earthenware, china included; the different varieties of which, and their respective values, depend upon the purity of the materials, the proportions of them, their more or less perfect mixture, and the attention paid to moulding, baking, and glazing them.

Combined with an alkali, it is the basis of all glass of commerce. It is an ingredient in granites and other stones used in building, and in almost all mortars and cements.

Section V. *Of the Metals which in combination with Oxygen produce Acids.*

Article 1. Molybdenum.

§ 1. Molybdenum is not very abundant. It is found native in the state of a sulphuret resembling black lead, and of an acid oxide combined with lead.

To obtain the pure metal, the sulphuret may be roasted at a red heat, and then distilled to dryness, three or four times over, with five or six parts of nitric acid; it may then be heated to a bright red heat, made into a paste with oil and a little charcoal, and exposed in a crucible to an intense heat. Or the ore, after roasting until reduced to a powder, may be dissolved in ammonia, the solution filtered, evaporated to dryness, redissolved in nitric acid, and dried. A white powder, which is molybdic acid, is produced. It may be reduced with charcoal as before.

This metal has a whitish grey colour when fresh broken, but its surface has a yellowish tint. It is so difficult of fusion, that it has been obtained in small grains only. It is brittle, and produces brittle compounds with other metals.

Its specific gravity is 8.6 according to M. Bucholz. When heated in air, it is readily oxidated.

§ 2. There appear to be three definite compounds of molybdenum and oxygen.

The *protoxide* appears to consist of molybdenum 1 atom 47, + oxygen 1 atom 8; = 55.

It is obtained by heating molybdic acid with charcoal, and is a brownish black powder; or, by drying the solution of molybdic acid in ammonia, and exposing it in a crucible covered with charcoal to a white heat. The oxide is found crystallized in texture, of a copper-brown colour. It does not combine with acids.

When tin is immersed in a solution of molybdic acid, a blue oxide is produced. Or when one part of molybdenum

is incorporated with two parts of molybdic acid, in boiling water, and evaporated at the temperature of 120°, a blue powder is produced, which has acid properties, and is called *molybdous acid*. The action of the atmosphere upon molybdenum converts it into this acid. It consists of molybdenum 1 atom 47, + oxygen 2 atoms 16; = 63.

Molybdic Acid is obtained by heating the ore with nitric acid as above directed. It is the white powder obtained by this process. On the application of heat, it is volatilized, and condenses in brilliant scaly yellow crystals. It slightly affects vegetable blues, and combines with alkalies. It appears to consist of molybdenum 1 atom 47, + oxygen 3 atoms 24; = 71.

It is soluble in 960 parts of water, producing a yellow solution, having a slightly sour taste, and reddening litmus.

Hot sulphuric acid dissolves molybdic acid; the solution, which is colourless while hot, becomes blue on cooling; the colour again disappears on applying heat. The colour is increased by adding soda. Muriatic acid dissolves it, forming a pale yellowish green solution, which becomes blue by alkalies.

The molybdate of ammonia is soluble, but not crystallizable.

The molybdates of potassa and soda precipitate most or all metallic solutions, forming molybdates.

The molybdates of gold, mercury, zinc, manganese, precipitated from their muriates, are white; of iron and tin, brown; of cobalt, rose-colour; of copper, blue. A diluted solution of fresh made muriate of tin is precipitated by molybdate of potassa of a beautiful blue.

Native molybdate of lead is met with; it is in yellow crystals of different shades.

Sulphuret of molybdenum is, as before stated, often found native. It has a soft laminated texture; it nearly resembles black lead both in texture and colour.

Neither molybdenum nor any of its compounds are used in the arts.

Article 2. Tungsten.

§ 1. Tungsten exists native in the ore called Wolfram, and in the state of tungstate of lime.

The pure metal may be obtained by fusing tungstate of lime with four times its weight of carbonate of potassa, and pouring upon the mass 12 parts of boiling water. On the addition of nitric acid, the peroxide of tungsten is precipitated; this is to be mixed with charcoal, and exposed to a strong heat.

Tungsten is very hard, brittle, and of a brilliant greyish white colour. It is very difficult to fuse, and has been obtained in small cohesive grains only. Its specific gravity is about 17.4.

§ 2. It forms with oxygen two oxides.

When the tungstic acid is exposed, in an ignited tube, to a current of hydrogen gas, a brown oxide is produced, which, if heated in the air, burns like tinder, again becoming tungstic acid.

The *protoxide* appears to be incapable of combining with acids or alkalies.

The *peroxide* of tungsten has many properties of an acid. It is tasteless, however, and insoluble in water.

When exposed to a violent heat, it passes through changes of colour, becoming in succession, a deeper yellow, greenish, grey, black. It appears to consist of tungsten 1 atom 96, + oxygen 3 atoms 24; = 120.

Tungstate of ammonia affords soluble scaly crystals, having a metallic taste.

The yellow oxide forms a deliquescent compound with potassa, from which it is precipitated by acids in the state of double salts.

Tungstates of the alkaline earths are readily produced

by boiling solutions of them with tungstic acid, and form soluble crystals.

Tungstate of magnesia produces semipellucid scaly crystals. Acids precipitate it in the state of triple compounds.

Tungstates of various metals may be formed also, which are insoluble.

By heating one part of peroxide of tungsten with four of sulphuret of mercury, a blackish grey sulphuret was formed, the mercury and oxygen being evaporated.

Article 3. Titanium.

§ 1. Titanium is found mineralized with oxygen, silica, and lime, in several places in Scotland, It is found also in Norway, and in the Alps, but it is more generally met with in small quantities in iron ores, and as it does not shew any attraction for iron, it appears to be generally left in the slag. An ore of iron containing about 14 per cent. of this substance has been found in the Isle of Skye. It is a brittle metal, but thin plates of it are somewhat elastic.

Some very small cubes, having the lustre of burnished copper, that were found adhering to the iron slag at the iron-works at Merthur Tydril, appeared to be titanium in the metallic state. They were examined by Dr. Wollaston, who found them to be electric conductors. Their specific gravity was 5.3. Their hardness was such as to scratch the hardest steel, crown glass, and even agate. They were cleaned, but not acted upon, by muriatic acid, nor by nitric, nitromuriatic, nor boiling sulphuric acid. They are infusible before the blow-pipe. They shew no attraction for tin, lead, copper, nor iron. A continued heat oxidates them, and they become purple or red, according to the thickness of the oxide. The combined action of nitre and borax dissolves them. The fused mass may be boiled in water to separate the oxide, which is soluble in muriatic acid.

§ 2. Titanium is said to form three oxides. The blue is produced by heating the metal in an open vessel. The red is the native oxide, as it exists in titanite.

Peroxide of Titanium may be obtained by the following process.

Rutilite, a native oxide of titanium, is to be fused with carbonate of potassa, dissolved in muriatic acid, and precipitated by ammonia. It is then to be digested with hydrosulphuret of ammonia, and afterwards in diluted muriatic acid, which leaves the pure peroxide.

It consists, according to M. Rose, of titanium 66, + oxygen 34.

It is not soluble in water, but reddens moistened litmus paper.

According to M. George, dry chlorine was passed over metallic titanium, without imparing the lustre; but on applying heat to it afterwards in a bent tube, a fluid gradually came over, and condensed, that was transparent, colourless, and of considerable density, emitting dense pungent fumes, resembling chlorine, and boiling at a little above 212°. A drop of water added to a few drops of the fluid, produced an almost explosive evolution of chlorine, and an elevation of temperature. When the water was not in excess, a solid salt was left—a muriate of titanium, that is soluble and deliquescent.

When the chlorine is not previously dried by muriate of lime, a similar salt is produced in the first instance.

The fluid first obtained, he considers as a perchloride of titanium, containing titanium 6.66 + chlorine 7.94, and the solid salt as a protomuriate of titania oxide 7 + muriatic acid 3.74. (Phil. Annals, No. 49.)

The peroxide combines with potassa, producing titanate of potassa, and with soda, producing titanate of soda. The proportion in which the combination takes place is such that the oxygen in the acid is to that in the base as two to one.

These compounds are decomposed by water, and acid titanates formed, consisting of titanic acid 83.15 + soda 16.85; and of titanic acid 82.33 + potassa 17.77.

It will not combine with acids; but in combination with sulphuric phosphoric, arsenic, oxalic, or tartaric acids, it forms soluble double salts.

The sulphurets which may be produced by decomposing the acid with sulphuretted hydrogen, consists of metal 49.17 + sulphur 50.83.

With iron, titanium forms a grey-coloured infusible alloy.

Article 4. Columbium.

§ 1. Columbium is a very rare metal. It was discovered by Mr. Hatchett, in a mineral which is the production of North America.

It was subsequently discovered by Mr. Ekeberg, in Sweden, who being unacquainted with the identity of the two discoveries, named it tantalite. This identity has since been shown by Dr. Wollaston.

Although the experiments of these chemists left no doubt of the body they examined possessing a metallic base, yet they never succeeded in reducing the oxide to a metallic state. M. Berzelius has been more fortunate. He succeeded, by boring cavities of the size of a goose quill, and about one inch and a half long, in pieces of charcoal, filling them with oxide, which had been strongly ignited, and closing them with a stopper of charcoal. They were then exposed in a Hessian crucible to an intense heat for an hour.

The colour of the metal was dark grey. When scratched with a knife, or rubbed upon a fine grindstone, it shewed a metallic lustre, and an appearance like iron. It is brittle, and hard enough to scratch glass. It is easily reduced to

powder, when it loses the metallic lustre. It is completely insoluble in nitric, muriatic, and nitro-muriatic acids. It burns at a red heat with a feeble flame, and produces a whitish oxide.

§ 2. The oxide was obtained by Dr. Wollaston, by mixing tantalite with two parts of borax, and five of carbonate of potassa, and fusing them in a platina crucible. The mass softened with water was heated with muriatic acid, which dissolving the iron and manganese, left the columbic acid in the state of a white powder.

It appears to consist of columbium 1 atom 144, + oxygen 1 atom 8; = 152.

Its specific gravity is about 6.

This oxide has the properties of an acid. It is insoluble nearly in muriatic acid, and wholly so in nitric or sulphuric acids. It is soluble in potassa, and its carbonate. It is soluble in a hot solution of soda, but separates as it cools.

The fresh precipitated oxide is soluble in tartaric, oxalic, and nitric acids.

Columbate of potassa crystallizes in white scales.

From a solution of this body, acids precipitate the columbic acid. It forms an insoluble salt with baryta. Infusion of galls produces an orange-coloured precipitate. It is not affected by hydrosulphurets, nor by ferrocyanate of potassa.

The fresh produced precipitate is readily soluble in tartaric, citric, or oxalic acids.

Columbium alloys with other metals, but has not been used.

Article 5. Chromium.

§ 1. The distinct nature of this metal was discovered by M. Vauquelin, in an ore in which it was combined with lead, denominated the red-lead ore of Siberia. It is this

metal which gives colour to the emerald. It has since been discovered, combined with iron in France, in America in considerable quantity, in Shetland and Pontroy.

It is a brittle metal, of a crystalline texture. In colour it resembles iron. It is extremely difficult to fuse. Its specific gravity is 5.9. It is said to be feebly magnetic.

§ 2. When the metal is heated in the air, it is converted into a *green protoxide*, that is not fusible nor decomposable by heat, but is easily soluble in acids. This oxide gives the green colour to the emerald, and may be used in enamelling. It gives colour to some other minerals also. Its compounds have not been much attended to.

The experiments of M. Berzelius and Dr. Thompson lead to the conclusion that the equivalent of chromium is about 28, and that of chromic acid 52, while the protoxide appears to contain half as much oxygen as the acid.

When nitrate of chromium is decomposed at a red heat, an insoluble brilliant brown *deutoxide* is produced, which is insoluble in acids, and in small proportion in alkalies.

To obtain the *chromic acid*, the native chromate of iron may be powdered with an equal weight of nitre, and exposed for some time to a red heat. The iron will be reduced to an oxide, from which the chromate of potassa may be separated by washing and filtration. Neutralize the alkali with nitric acid, and precipitate with muriate of barytes. Dissolve the chromate of barytes, while moist, in diluted nitric acid, and then precipitate the barytes with sulphuric acid, added in such proportion that neither barytes nor sulphuric acid remain in solution. Evaporate to dryness, and keep up the heat as long as nitrous acid escapes. The red powder which is left is chromic acid, and may be further purified by solution and crystallization.

When this acid is mixed with charcoal, and exposed to an intense heat in a blast furnace, the metal is reduced.

This acid has a sour metallic taste. When exposed to a

red heat, a part of the oxygen escapes, and the deutoxide is produced.

§ 3. *Chromate of Potassa* crystallizes in slender prisms of deep orange yellow colour. One grain of this salt will communicate a perceptible yellow tint to six pounds of water. Its taste is a nauseous penetrating bitter. It is soluble in two parts of water at 60°. Boiling water dissolves any quantity of it.

It consists according to Dr. Thomson's analysis of chromic acid 1 atom 52, potassa 1 atom 48; = 100.

When to a solution of these crystals as much sulphuric acid is added as renders it sensibly acid, if set aside for a day, crystals of bichromate of potassa are formed consisting of chromic acid 2 atoms 104, + potassa 1 atom 48; = 152.

They are of a beautiful and intensely deep orange colour in the mass appearing red.

They dissolve in about ten parts of water at 60°. They redden vegetable blues.

The chromates of ammonia, potassa, soda, and magnesia are all soluble, crytallizable salts; of a bright yellow or orange colour. Chromates of baryta and lime are less soluble.

By precipitating metallic salts with the alkaline chromates, various insoluble chromates may be formed. Thus, chromate of silver is precipitated crimson, chromate of lead is the beautiful pigment called chrome yellow. As the proportion of chromic acid increases, the colour approaches to orange colour. Chromate of copper is a beautiful apple green; chromate of uranium yellow; chromate of mercury red.

The solutions of tin, zinc, platinum, nickel, cobalt and gold are not precipitated by alkaline chromates.

The beautiful colours produced by the combinations of the oxides of chrome, have rendered it a valuable auxiliary to the enameller, the painter, and the calico-printer. It is

probable that as its compounds are further investigated its uses will be extended.

Article 6. Antimony.

§ 1. Antimony sometimes, although rarely, occurs nearly pure in the metallic state, sometimes in the state of an oxide, but more frequently combined with sulphur, sometimes in conjunction with copper, nickel, arsenic, lead, iron, or silver. In these states it is found in Cornwall, Germany, Saxony, Dauphiny, Hungary, and other places.

It is usually obtained by decomposing the sulphuret, or common antimony, as it is called in commerce.

Mix three parts of the sulphuret, with two of common tartar, inject the mixture, by spoonfuls, into a red hot crucible; and keep the mass for a short time at a red heat. When cold the metal will be found at the bottom. If it be required to be very pure, reduce it to fine powder, and dissolve it in nitromuriatic acid. On pouring the solution into water, a white precipitate falls, which when dried may be mixed with twice its weight of tartar, and heated as before.

This metal is of a dullish white silver colour, scaly and very brittle. It crystallizes as it cools. It fuses at a little above 800°. At a high temperature, it may be distilled. Its specific gravity is from 6.7 to 6.8.

It is not much affected by atmospheric air. When heated it burns with great energy, and brilliancy, in oxygen gas; producing an oxide which appears in the form of a dense yellow smoke.

Chemists are not agreed as to the number of oxides that antimony produces; nor even as to their proportions. M. Berzelius describes four oxides, as resulting from his experiments on the subject; but the first which he obtains by

the slow action of a moist atmosphere; or by making the metal the positive conductor of a voltaic battery, is scarcely shewn to be a definite compound.

It appears that antimony produces three oxides.

§ 2. *The Protoxide* is obtained by pouring muriate of antimony, into a solution of potassa; and washing the precipitate with water.

It is the basis of all the active preparations of antimony that are used in medicine. It is fusible, volatile, and soluble in cream of tartar, and in other acids.

§ 3. When antimony is exposed to air at a bright red heat, it is volatilized and condenses in delicate needles, formerly called argentine flowers of antimony. It must not be too much ignited. This oxide has a perfectly white colour. It is the deutoxide or *antimonious acid*. When fused with a fourth part of antimony the protoxide is produced. Its compounds are antimonites.

Antimonic Acid. When one part of antimony is fused for an hour with six parts of nitrate of potash, the mass washed with cold, then with boiling water, and digested with a little nitric acid, a white antimoniate of potassa is formed. When decomposed by muriatic acid, washed and gently heated, it has a fine lemon-yellow colour. It is insoluble in water, and reddens vegetable blues. Its compounds are antimoniates.

The same oxide appears to be obtained by dissolving antimony in nitric acid, evaporating to dryness and exposing the mass during several hours to a temperature of about 500°.

This is the peroxide; 7¼ parts when exposed to a red heat parted with oxygen, and a white oxide was left weighing seven parts.

Different proportions are assigned to the oxides by different chemists. Those assigned by Dr. Thompson correspond with the atomic theory, and are perhaps the most

correct. According to this arrangement, the equivalent or comparative weight of the atom of the metal is 44, and it is combined with oxygen in the following proportions:

	Antimony.	Oxygen.	
Suboxide (of Berzelius)	1 atom = 44,	½ atom =	4 = 48
Protoxide	1 atom = 44,	1 =	8 = 52
Deutoxide	1 atom = 44,	1½ =	12 = 56
Peroxide	1 atom = 44,	2 =	16 = 60

The protoxide of antimony alone has the property of combining with acids, and producing neutral saline compounds.

The deutoxide and peroxide do not combine with acids, but on the other hand combine like acids with alkaline and earthy bases, and are, in consequence, termed by Berzelius, antimonious, and antimonic acids.

When antimony has been exposed to the action of sulphuric acid, a part of the acid is decomposed, and supplies oxygen to convert the antimony into a protoxide. A subsulphate and an acid sulphate may be produced.

§ 4. Antimony combines with chlorine in one proportion, forming *Chloride of Antimony*.

When the powdered metal is poured into the gas, they combine with inflammation.

The chloride is produced also when five parts of corrosive sublimate and two of the powdered metal are mixed and distilled. It consists of antimony 1 atom 44, + chlorine 1 atom 36; = 80.

It is usually called butter of antimony, on account of its consistence when fresh made, which is that of a soft crystallized solid, that becomes liquid at a gentle heat, or after being kept for some time. The addition of water decomposes it, as it does most other chlorides; but instead of a muriate of antimony, a hydrated submuriate of the protoxide falls down, and muriatic acid is found in the solution.

Iodide of Antimony, a dark compound, is decomposed by

water, hydriodic acid, and oxide of antimony, being produced.

§ 5. *Sulphuret of Antimony* is readily produced by melting the bodies together in due proportions. It consists of antimony 1 atom 44, + sulphur 1 atom 16; = 60.

This sulphuret, according to M. Proust, may be kept in fusion for a length of time without loss; but if an additional proportion of sulphur be added, it readily escapes. Neither does it readily combine with more antimony.

Sulphuret of antimony exists native in great abundance, and is well known in commerce by the name of crude or common antimony.

It is a substance of a dark grey colour, thickly striated with lines of a brilliant metallic lustre, and produced by parallel or radiated crystallizations. Its specific gravity is about 4.4.

When this sulphuret is roasted slowly in the open air, a part of the sulphur escapes, oxygen is absorbed, and a grey powder is produced. When this is exposed to a sufficient heat, it fuses into a very dark brown compound. When the quantity of sulphur that is left is large, the composition is called by druggists liver of antimony, or crocus metallorum; when the sulphur is less than about 10 per cent. the compound is semi-transparent, of a claret colour, and is called glass of antimony. It consists chiefly of protoxide of antimony, fused with about ten per cent. of sulphuret, and with a small quantity of silica, from its action on the crucible.

§ 6. When equal parts of pearlash and sulphuret of antimony are mixed, fused, powdered, and boiled in ten times their quantity of water, and the liquor filtered while hot, a reddish brown precipitate falls down as the solution cools, which is called *kermes mineral*. It appears to consist of protoxide of antimony 1 atom 52, + sulphuretted hydrogen 1 atom 17; = 69.

A second precipitate may be obtained from the cold solution by the addition of diluted sulphuric acid. It is of an orange-red colour, and contains a larger proportion of sulphur. It is called golden or *precipitated sulphur of antimony*.

When sulphuret of antimony is deflagrated with four times its weight of nitre, the metal is converted into a peroxide or acid, and combines with the potassa left by the decomposition of the nitre, forming an antimoniate of potassa, which may be decomposed by muriatic acid.

Phosphorus and its acids do not produce any compounds of importance with antimony.

§ 7. *James's Powder* is a variable, heterogeneous, unchemical mixture of the different oxides of antimony, with phosphate of lime, containing from four to eight tenths of the latter, according to the heat that has been employed.

§ 8. The salts of antimony are not of much importance. The protoxide forms salts with the different acids, which are little used, except the tartrate of potassa and antimony, or emetic tartar, which is much used in medicine. The peroxides, as medicines, are inert. The muriate is used in farriery as a caustic.

The antimonious and antimonic acids combine with ammonia, the alkalies, and the oxides, producing two classes of compounds, called antimonites, and antimoniates.

The salts of antimony are precipitated of an orange colour by sulphuretted hydrogen. The oxide is separated from many of them by the addition of water.

Antimony may be alloyed with most of the metals. It renders the malleable metals brittle. Even the fumes of antimony affect the ductility of gold.

One part of antimony to sixteen of lead, with a small portion of copper, is the compound used for printers' type. Without the copper, it forms the plates on which music is engraved. One part of antimony, with a fourth of copper, and twelve parts of tin, forms the finest pewter.

Article 7. Arsenic.

§ 1. Arsenic is a metallic body which, in consequence of its strong attraction for oxygen, sulphur, lime, silver, cobalt, lead, copper, and other metallic bodies, is seldom met with native, in a pure metallic state. But it is abundant in nature, variously combined and mineralized with the bodies named.

The arsenic of commerce is an oxide obtained by sublimation, in roasting certain ores, chiefly of cobalt; the vapour being condensed in flues adapted to the purpose. Its true nature and properties were first elucidated by M. Scheele, one of the most acute chemists of Sweden, and indeed of Europe.

To obtain the pure metal, two parts of common arsenic of commerce may be mixed with black flux, which is a fused mixture of charcoal and potash. The whole may be put into a crucible or fusion-pot, to the opening of which another fusion-pot is securely luted. A red heat should be applied to the inferior part of the lower crucible, while the upper is kept cool. The arsenic will be reduced to the metallic state, and sublimed into the upper vessel, round the sides of which it will adhere. It is of a brilliant steel colour, with a blueish lustre. It is very brittle, and readily powdered. Its specific gravity is 8.3.

It is very fusible; it evaporates at 356° unchanged in close vessels. At a red heat it takes fire, burns with a blue flame, producing an abundant white smoke, and accompanied with a strong smell resembling garlick.

Arsenic and all its compounds are violent poisons.

Chemists do not agree in relation to the smallest combining proportion of arsenic. It may be estimated provisionally at 76, the proportion adopted by several chemists.

When the metal is left exposed to the air, it becomes tar-

nished; this tarnish gradually becomes thicker, and at length the metal is converted into a bulky black powder, consisting, according to M. Berzelius, of 100 parts of metal and 8.5 of oxygen. When heated in a close vessel, it is decomposed, arsenic is produced, and a white oxide.

It combines in two permanently definite proportions with oxygen; the compounds resulting are both sapid, soluble in water, and combine as acids with other metallic oxides. They, in consequence of these properties, are called acids; and to distinguish them according to their different proportions of oxygen, they are named arsenious and arsenic acids.

§ 2. *Arsenious acid* is the common white arsenic of commerce. It comes chiefly from the zaffre and smalt works in Saxony.

It is a white, hard, brittle, inodorous body, which breaks with a choncoidal fracture. It is generally opaque, but is frequently intermixed with transparent portions. Its taste is acrid. It is composed of arsenic 1 atom 76, + oxygen 3 atoms 24; = 100.

It is volatile at about 380°.

It is soluble in about 14 parts of boiling water; more than three-fourths precipitating as it cools; but it is of difficult solubility in cold water.

It combines as an acid with alkaline and earthy bases, producing a class of salts called arsenites.

The arsenites of potassa, sôda, and ammonia, may be formed by boiling the respective alkalies with arsenious acid. They are soluble and uncrystallizable. The arsenites of baryta, strontia, lime, and magnesia may be formed in the same way. They are soluble with difficulty. The arsenites of the different metallic oxides may be formed by decomposing soluble salts of the respective metals, with the alkaline arsenites. Thus when arsenite of ammonia is added to nitrate of silver, a precipitate first white but soon be-

coming yellow, is produced, which is an arsenite of silver. An excess of ammonia dissolves it. Arsenite of potassa, when added to a solution of sulphate of copper, produces a fine apple-green precipitate, which is an arsenite of copper. It is known by the name of Scheele's green, and is used as a pigment.

The white arsenites of zinc, lead, antimony, and bismuth are produced in the same manner.

Arsenite of cobalt is pink, of iron dull green, of uranium bright yellow.

Native arsenious acid is met with. Native arsenite of lead is found in Spain, France, and Siberia.

Arsenious acid unites by fusion with a mixture of the earths and alkalies, producing glass, and increasing the transparency of it.

§ 3. *Arsenic Acid* may be obtained by repeatedly treating arsenious acid with nitric acid; or 1 part of muriatic and 6 of nitric may be gradually distilled from 2 parts of arsenious acid, gradually raising the heat at the end of the operation, until the bottom of the retort become red hot.

It consists of metal 1 atom 76, + oxygen 5 atoms 40; = 116.

Arsenic acid fuses into a transparent glass, that becomes opaque in cooling. It has a very sour, metallic, acrid taste. It is uncrystallizable, and slowly deliquescent. Its specific gravity is 3.4. It is soluble in 6 parts of cold water, and in 2 of boiling water. It assumes, when evaporated, a gelatinous consistence. The solution effervesces in alkaline carbonates.

It unites with alkalies, and oxides, producing a class of salts called arseniates and bin-arseniates.

There is an analogy between arsenious and arsenic acids. Although their soluble salts may be accurately neutralized in solution, yet they both crystallize with an excess of al-

kali. Their combinations with the earthy and metallic oxides are insoluble; their respective salts, however, are very different.

Arsenate of Ammonia is produced by saturating arsenic acid with ammonia. It crystallizes on evaporation, in rhomboidal prisms. When gently heated, the crystals effloresce, and ammonia is evolved; as the temperature is raised, water is produced; at length nitrogen is evolved, and oxide of arsenic sublimed.

Arseniate of Potassa may be formed by distilling together equal parts of nitrate of potassa and arsenious acid. It crystallizes in quadrilateral prisms, terminated by four-sided pyramids. The crystals are permanent; have a saline, cooling taste, are soluble in 5 parts of cold water, and appear to consist of, arsenic acid 65, potassa 27, water 8; = 100.

Arseniate of Soda produces large rhomboidal efflorescent crystals. It has a cooling taste, milder than that of carbonate of soda. When heated, the crystals dissolve in their own water. They are soluble in ten or eleven times their weight of cold water. The alkaline property prevails in these crystals.

Arseniates of the alkaline earths, and oxides, are, for the most part, insoluble; and are produced by decomposing their respective soluble saline compounds, with one of the alkaline arseniates. Most of them are soluble in excess of acid, and form bin-arseniates.

Some of these arseniates are found native; that of iron for instance, of copper, of lead, of cobalt.

§ 4. *Chloride of Arsenic.* If powdered arsenic be poured into chlorine, it burns and produces a whitish compound. The same compound is obtained by distilling six parts of perchloride of mercury, (corrosive sublimate) and one of arsenious acid. An unctuous substance is produced, called butter of arsenic. It is deliquescent, and it is decomposed

by water; muriatic acid is produced, and arsenious acid precipitated.

When chlorate of potassa, and arsenic acid, are separately powdered, and cautiously mixed; on applying an ignited body, the mixture inflames with a rapidity that produces detonation. The resulting compound has not been examined.

§ 5. *Arseniuretted Hydrogen* may be obtained, by adding to a mixture of zinc, or iron filings, and dilute sulphuric acid, a little powdered white arsenic. Or an alloy may be prepared, by fusing, for two hours in a strong heat, in a well-closed crucible, equal parts of antimony and of cream of tartar, with half as much common white arsenic; of which alloy, a little may be introduced under an inverted jar filled with water; arseniuretted hydrogen is given out.

This gas is colourless and transparent. The specific gravity of it, when pure, is about 0.53. It has a *fetid garlick-like smell*. It extinguishes flame, is little absorbed by water, and does not change vegetable blues. It burns with a pale blueish white flame, a white dense smoke, and an alliaceous smell. Fired as it issues from a capillary tube into oxygen gas, it burns with a splendid blue flame.

100 cubic inches of the gas evolved 140 cubic inches of hydrogen, and about 25 grains of metallic arsenic: but it requires further examination.

Mr. Stromeyer says, that at 22° it may be converted into a liquid. Chlorine decomposes it, producing muriatic acid, and a solid brown hydruret. The same hydruret falls down when the gas stands for a time over water, or when it is slowly burnt.

§ 6. Sulphur and arsenic combine in two proportions.

The red Sulphuret is obtained by fusing at a gentle heat, a mixture of arsenic, or arsenious acid, with sulphur.

Its specific gravity is 3.7. It consists of 100 parts of

arsenic, and 43.6 of sulphur. It crystallizes on cooling, and breaks with a vitreous fracture.

The yellow Sulphuret is produced by dissolving white arsenic, or arsenious acid, in muriatic acid; and precipitating by hydrosulphuret of ammonia. A fine yellow precipitate falls, consisting of arsenic 100, sulphur 64.

Some chemists consider these sulphurets to be varieties of the same compound.

Both are found native, and are known in commerce by the respective names of realgar, and yellow orpiment. They are used as pigments, and for dying.

Sulphuric acid when boiled upon arsenic is decomposed.

Other compounds of arsenic there are, but they are of no value.

Arsenic produces alloys with most of the metals. Generally it whitens them, and renders them brittle. With copper it produces a white, scarcely malleable alloy.

§ 7. The powerfully poisonous property, and the comparative cheapness of arsenious acid, or white arsenic, has long brought it into general use for destroying rats; and consequently, has introduced a knowledge of its poisonous properties to the most unlettered and unprincipled of the vulgar. It is, therefore, a very frequent instrument of murder.

The attention of physiologists, and chemists, have been long directed to the endeavour to point out, on the one hand, such symptoms and appearances as this destructive poison produces on the sufferer; and on the other, such tests and evidences of the presence of this poison, even in the most minute quantity, as may lead to its detection.

From the moment that poison is suspected, every thing that passes from the body of the patient should be preserved; for the vomitings, and other evacuations, generally discharge the whole of the poison before life is destroyed.

When arsenic is present, a part of it will be dissolved in the fluids of the stomach and intestines, therefore they should be preserved. The undissolved part of arsenic, from its great specific gravity compared to animal or vegetable matter, falls as a heavy body to the bottom of the vessels in the state in which it was administered; generally a white heavy powder more or less gritty; and may be washed out by repeated small portions of cold water: or the stomach and upper intestines may be macerated in hot water, with a little ammonia to increase the solubility of the poison, as was directed by Dr. Ure.

The respective fluids that have been removed from the stomach and intestines, should be filtered, and the solid part boiled in a due proportion of distilled water. Any heavy matter, which is suspected should be separated, triturated in a glass, or Wedgewood's mortar, and boiled in water by itself: and the trituration and boiling should be repeated if necessary. These respective liquids should also be filtered; when they may be mixed and evaporated down to a small quantity. White arsenic remains soluble in 70 or 80 times its weight of cold water, when previously boiled in it; consequently an ounce of water will hold in solution 6 grains.

A few drops of this solution may be spread over a plate of glass placed upon white paper, in a good light. If it contain arsenic, most of the following appearances will be observed.

On touching a spot with a clean glass rod dipped in fresh made liquid sulphuretted hydrogen, a gold yellow tint is produced.

When less than one drop of diluted nitric acid is added to another part, a drop of an alkaline sulphuret will produce a similar precipitate.

When another part is touched with a weak solution of ammonia, and then with a clean glass rod dipped in a

solution of nitrate of silver, a bright lemon-yellow precipitate appears. When common salt is present, a dense white precipitate is produced, which when arsenic also is present, is accompanied or followed by a yellow colour.

Or a stick of nitrate of silver may be drawn three or four times across a small space of the surface, and then touched with a rod dipped in ammonia. This will rather brighten the colour of the arseniate of silver. If there be no arsenic the colour will be darker, or turn to a dull greenish hue.

When another spot is touched with a solution of acetate of copper and ammonia, its blue colour is changed to a bright apple green.

When, to another spot, a drop of a solution of potassa is applied, on the addition of a drop of a strong solution of sulphate of copper, a dense apple-green precipitate appears.

When another part is touched with a drop of lime-water, a white precipitate is produced. Touch this with diluted nitric acid, and then with a drop of a solution of hydrosulphuret of ammonia, and the precipitate is changed to a gold yellow.

Accidental mixtures may probably affect some one of these tests, but not the whole of them.

When, after this examination, it is concluded that arsenic is present; the solution should be evaporated until it becomes nearly dry, well mixed with half its weight of black flux, and put into a long narrow glass tube that is closed at one end and exposed to heat, while the upper part of the tube is kept cool. The metallic arsenic will sublime and condense a little above on the sides of the tube, having a bright dark steel lustre. Upon heating that part of the tube, the sublimed metal is again volatilized, and again condensed in the cooler part of the tube above.

For further satisfaction, the lower part of the tube may be separated, and the sublimed metal collected. A bit of it put upon a red hot iron or cinder, will evaporate, producing a smell resembling garlick.

Another portion rubbed with sulphate or acetate of copper and ammonia, will produce a dense apple-green precipitate of arsenite of copper.

Another portion put between two polished plates of copper slightly touched with oil, and exposed to a red heat, will produce a white alloy on the surface of the copper.

Or sulphuretted hydrogen may be passed through the solution until no more is retained. The coloured precipitate may be separated by a filter, dried, and fused at a red heat, in a similar tube, with its weight of caustic potash. A sulphuret of potassa will be produced, and the metal sublimed as before. But it will occasionally happen, that a person dies after having suffered all the symptoms produced by this poison, and no arsenic can be found; it having wholly escaped with the matter vomitted up, and removed before the presence of poison was suspected. The diseased stomach should not, therefore, be hastily destroyed. More may be learned, generally, from its appearance, than from its analysis.

The common-place experiment of dropping a suspected substance into a fire, and trying if it has a garlick smell, is not to be depended upon. White arsenic has no such smell, until it parts with its oxygen. On the other hand, an inexperienced person may be misled by the smell of sulphuretted hydrogen, or sulphurous acid.

Section VI. *Of the Metals producing Oxides not decomposable by Caloric alone.*

Article 1. Tellurium.

§ 1. Tellurium is met with in Transylvania and Siberia, in combination with gold, lead, silver, copper, and sulphur; and iron sometimes superadded.

To obtain this metal, the ore is acted upon by nitro-

muriatic acid. The diluted solution being precipitated by potassa, which must be added in excess, the clear liquid must be decanted. It contains the oxide of tellurium, which is precipitated white by saturating the potassa with muriatic acid. This, when dried, may be mixed with about a tenth part of charcoal, or with a little oil, and exposed to heat in a glass retort. The tellurium is distilled, and condenses again into small brilliant metallic drops upon the upper part of the retort.

Tellurium is of a bright white colour with a greyish tint. It becomes fluid below ignition, and is the most volatile of the metals, except arsenic. Its specific gravity is 6.1. It is very brittle and has a foliated fracture.

When heated in the air it burns brilliantly with a blueish green flame, and a dense vapour, exhaling a peculiar nauseous smell, which appears to be consequent upon the presence of a little selenium.

Under the blow-pipe tellurium inflames with violence amounting to detonation.

§ 2. It forms one oxide only which is of a yellowish white colour and consists of, according to Klaproth, 100 metal to 20.5 oxygen, to Berzelius 100 + 27.83. When heated on charcoal it is suddenly reduced and evaporated.

Tellurium combines with chlorine into an easily fusible substance, white, and semi-transparent, which is volatile at a strong heat, crystallizes as it condenses, and is decomposed by water.

It consists of 1 atom of each ingredient.

Muriatic acid dissolves tellurium and so does nitro-muriatic acid. When the solution is dried and heated a chloride of tellurium is produced. When water is added to it, a white powder is precipitated, which is redissolved by the further addition of water.

From these solutions, the tellurium is precipitated in the metallic form by tin, zinc, and iron.

Alkaline carbonates precipitate a white hydrated oxide, which a further addition of the carbonate redissolves.

Iodide of tellurium is of a deep brown colour and is decomposed by water.

When oxide of tellurium potassa and a little charcoal are exposed to heat, an alloy of tellurium and potassium is produced. On exposing this to the action of diluted sulphuric acid, *telluretted hydrogen* is obtained.

This gas in smell somewhat resembles sulphuretted hydrogen. It burns with a blueish flame, and oxide of tellurium is precipitated from the vapour.

It is absorbed by water, the solution is at first transparent but brown; it gradually becomes muddy, and at length lets fall the metal in the state of a brown hydruret.

Chlorine converts it into a hydrochlorate, that is precipitated white by alkaline carbonates, and black by hydrosulphurets.

When washed it does not change vegetable blues; but it unites with alkalies, and the compound precipitates many of the metals.

According to the analysis of M. Berzelius it appears to consist of about 100 parts of metal to 2 of hydrogen.

When tellurium is made, in contact with water, a part of the negative conducting surface of a voltaic battery, a brown powder forms which appears to be a compound of hydrogen and tellurium. The oxide of tellurium has also the property of combining as acids do with alkalies, alkaline earths, and various oxides; and thus producing a class of compounds that may be called tellurates.

When tellurium is mixed with nitrate of potash, and heated, it burns, and the remaining mass being dissolved in boiling water; deposits, as it cools, a white crystalline powder, which is tellurate of potash. It is soluble with some difficulty in water.

When the solution is added to soluble compounds of lime,

baryta, strontia, copper, or lead, insoluble tellurates of these bodies are produced. This solution, and these compounds require further examination.

This metal is found in too minute a quantity to be applied to any use in the arts.

Article 2. Cadmium.

Cadmium was discovered in 1817, by M. Stromeyer, in examining the productions of carbonate of zinc from Silesia. It has since been discovered in several other ores of zinc, and has been detected in the zinc of commerce. At Bristol it is found adhering to the roofs of the vaults in which zinc is distilled; for in consequence of its greater volatility it rises before the zinc in distillation; and might probably be obtained in considerable quantity.

The metal may be procured by dissolving the ore, or body suspected to contain it, in muriatic acid. The solution evaporated to dryness, should be re-dissolved in water. When cadmium is present a bright yellow precipitate is produced by sulphuretted hydrogen. A plate of iron will precipitate all the metallic salts, which iron is capable of decomposing; but not affect the cadmium. This latter may be precipitated in the metallic state by a plate of zinc. The precipitate may then be purified from iron by distillation in close vessels.

Cadmium has a strong resemblance to tin, in colour, lustre, and in crackling when bent. It is rather more tenacious, cuts smooth, is ductile, can be drawn into fine wire, and may be reduced to thin plates; but scales when long beaten. Its specific gravity is from 8.6 to 9. Its evaporating temperature is a little above that of mercury. It condenses in drops which shew a distinct crystalline form. It melts below red heat.

It is little acted upon by atmospheric air until heated;

when it combines with oxygen, producing an orange-coloured oxide, which is sometimes very brown, and which, according to M. Stromeyer, consists of metal 100 parts to 14.35 of oxygen, or 1 atom cadmium = about 56 + 1 of oxygen 8; = 64.

This oxide is not volatile in heat, is soluble in nitric acid, and in ammonia; but not in its carbonate. The solution is precipitated by potassa, or by its carbonate; and may thus be separated from zinc.

It combines readily with acids producing crystallizable salts, from which it is precipitated by the alkalies, in the state of a hydrated white oxide, which is soluble in ammonia. It is readily precipitated by zinc.

Sulphuretted hydrogen produces an orange yellow precipitate; prussiate of potash a white one.

Cadmium will alloy with most of the metals.

Article 3. Zinc.

§ 1. Zinc is met with in the state of oxide, and also united with carbonic acid, in the ore called calamine; and in the state of yellow, brown, and black sulphurets in blende. Sulphurets of zinc occur in many of the British lead mines, sometimes containing cadmium, iron, copper, arsenic, alumina; silica or fluoric acid also, in varying proportions.

The zinc of commerce is usually obtained by first picking the ore, and exposing it in a reverberatory furnace, to a dull red heat. By this operation the carbonic acid, or the sulphur are removed. Then it is ground, washed and mixed with an eighth of its weight of charcoal. It is then put into large crucibles or pots, several of which are placed in one furnace; each pot having an iron tube passing into it through its bottom, and passing downward through the

floor of the furnace, into water. The pots are closely covered and stopped, and a red heat applied. The metal is volatilized, and passes through the tubes into the water. It is melted again and cast into cakes.

This zinc generally contains some cadmium, lead, iron, or other impurities. When wanted perfectly pure, it should be dissolved in diluted sulphuric acid, and a plate of zinc immersed for some days. The solution should be decanted; the oxide precipitated by carbonate of potassa, and ignited with charcoal in a covered crucible.

Zinc is a brilliant blueish white metal. Its specific gravity is 7. The weight of its atom is 33. It is malleable at a temperature of from 220° to 300°, and may be extended, by rolling, into thin plates, or drawn into a weak wire; but at the temperature of the atmosphere it is brittle, and also as it approaches its fusible point. It melts at about 680°, and on cooling forms regular crystals.

It becomes in time covered with a grey oxide.

§ 2. When exposed to heat it becomes oxidated very fast. At a red heat it burns with a bright white flame; and is converted into a very light flocculent oxide, which is, in part, carried up in the current of air. It was formerly called philosopher's wool. This oxide is not volatile; exposed to an intense heat it vitrifies, affording a clear yellow glass. It is white, tasteless, and soluble in alkalies.

It consists of 1 atom zinc 33, + 1 oxygen 8; = 41.

This oxide is procured also by precipitating the sulphate with an alkali. It is produced also by exposing zinc to the vapour of water at a high temperature. No other oxide is known.

§ 3. *A Chloride of Zinc* may be formed, by heating thin leaves of zinc in chlorine; or by evaporating muriate of zinc to dryness, and exposing it to heat in a close vessel.

It is a fusible compound, first softening like wax: and

volatile below a red heat, in the open air. It is acrid and corrosive. It consists of 1 atom zinc 33, + 1 atom chlorine 36; = 69.

Formerly it was called butter of zinc. It is deliquescent, and water converts it into a muriate.

Muriate of zinc is very soluble, and difficult to crystallize. If exposed to heat in the air, the muriatic acid escapes; if in a close vessel, it is converted into a chloride.

§ 4. *Nitrate of Zinc* crystallizes, with difficulty, in four-sided prisms; which are soluble in water and alkohol.

The dry salt consists of oxide of zinc 1 atom 41, + nitric acid 1 atom 54; = 95.

Liquid ammonia readily dissolves oxide of zinc. On a plate of copper being immersed in the solution, a part of the zinc is precipitated in the metallic state, and copper dissolved in its place.

Carbonate of zinc may be obtained by precipitating sulphate of zinc with a carbonate of potassa.

It consists of oxide of zinc 1 atom 41, + carbonic acid 1 atom 22; = 63.

It is white, insipid, and insoluble: it is met with native in calamine.

§ 5. *Sulphuret of Zinc*, when artificial, is of a yellowish brown colour. It consists of zinc 1 atom 33, + sulphur 1 atom 16; = 49.

Zinc forms crystalline compounds with hyposulphurous, and sulphurous acids.

§ 6. *Sulphate of Zinc* may be obtained by dissolving zinc in sulphuric acid. A portion of water is decomposed to supply the zinc with oxygen, and the hydrogen gas is evolved. This gas, however, holds in solution a portion of the metal, and, in consequence, if burnt directly after its production, produces a higher temperature, and a distinctly blue flame. When the gas is preserved over water, the metal will be deposited in a film on its surface.

Sulphate of zinc forms into four-sided prismatic crystals, containing, sulphuric acid 1 atom 40, oxide of zinc 1 atom 41, water 7 atoms 63; = 144.

It is soluble in 2½ parts of water at 60°. It is sometimes found native.

The sulphate of zinc, or white vitriol of commerce, is prepared by decomposing the native sulphurets; by exposure to atmospheric air, and subsequent solution in water.

§ 7. The combinations of zinc and phosphorus have scarcely been examined.

Fluate of zinc forms opaque white crystals, soluble in ammonia.

Zinc produces some triple salts.

With boracic acid it affords a white insoluble powder.

The saline compounds of zinc are mostly soluble in water and colourless, soluble in sulphuric acid, form a yellowish precipitate with ferrocyanate of potash, and are precipitated white by the alkalies.

Zinc enters into only one useful alloy: with copper it forms brass. Its strong attraction for oxygen, and the strong attraction of the oxide for acids, producing soluble compounds, renders it unfit for most uses. It is very conveniently used in the construction of voltaic batteries.

Article 4. Bismuth.

§ 1. Bismuth occurs native in Cornwall, in Saxony, and in Siberia. It occurs also, combined with oxygen, copper, sulphur, lead, iron, carbonic acid, and sometimes with nickel, cobalt, and tellurium.

Pure bismuth may be obtained by dissolving the bismuth of commerce in nitric acid, and precipitating its oxide with pure water. The oxide may be washed, dried, and reduced with black flux.

It is a brilliant white metal, with a tint of red. Its crys-

tallized structure is very distinct. It appears made up of cubes adhering to each other. Its specific gravity is 9.8, and is increased by hammering. It is hard, but scarcely malleable, and not ductile. It is somewhat sonorous. It is fusible at 476°. It is volatile in close vessels, at a high temperature. It is slightly tarnished by the air, but is not acted on by water. When moderately heated, it becomes covered with a greyish oxide. When ignited, it burns with a blueish flame, producing an abundant yellow smoke, which is easily condensed.

§ 2. This is the *Oxide of Bismuth*, consisting of 1 atom bismuth 71, + 1 of oxygen 8; = 79.

It is easily fusible into a yellow transparent glass. Like oxide of lead, it attracts and fuses the oxides of other metals; and might, in consequence, be used in refining gold and silver.

§ 3. Bismuth, reduced to powder, takes fire in chlorine and produces a *chloride of bismuth*, or it is produced by the evaporation and fusion of muriate of bismuth.

It consists of 1 atom of bismuth 71, + 1 atom of chlorine 36; = 107.

It may be sublimed. From its consistence, it has been called butter of bismuth. It deliquesces in keeping, and becomes a muriate.

Iodine and its acids combine with bismuth.

§ 4. *Nitrate of Bismuth* is prepared by dissolving the metal in nitric acid, diluted with half its quantity of water. An energetic action follows, with an extrication of nitric gas. The nitrate crystallizes in small quadrangular prisms.

It consists of bismuth 1 atom 71, + nitric acid 1 atom 54.

Upon pouring pure water upon this salt, a subnitrate precipitates in the state of a very fine white powder, which

is known in commerce by the names of pearl white, magistery of bismuth, and a super-nitrate is left in the liquid.

Ammonia precipitates the oxide from this salt, and redissolves it when added in excess.

A letter written with nitrate of bismuth is invisible; dip it in water, and the letters become opaque and legible. Hence it forms a sympathetic ink.

§ 5. Bismuth combines with sulphur, forming a blue grey sulphuret, with a metallic lustre, and a bisulphuret is also known.

The former consists of bismuth 1 atom 71, sulphur 1 atom 16.

The latter of bismuth 1 atom 71, sulphur 2 atoms 32.

§ 6. Sulphuric acid acts on bismuth when heated, a part of the acid becoming decomposed.

The sulphate is composed of bismuth 1 atom 71, + sulphuric acid 1 atom 40; = 111.

The addition of water decomposes it into a supersulphate, and an insoluble subsulphate.

The alkaline hydrosulphurets precipitate solutions of bismuth, of a deep brown.

§ 7. Bismuth forms alloys with different metals. It is sometimes an ingredient in type-metal; it renders gold and platinum brittle. It gives additional fusibility to several metals, and is, in consequence, an ingredient in some solders. In general, it renders the metals alloyed with it more prone to oxidation.

An alloy, composed of 8 parts of bismuth, 5 of lead, and 3 of tin, melts in boiling water, and is therefore sometimes used as a play-thing. It is rendered still more fusible by the addition of a little mercury.

Article 5. Lead.

§ 1. Lead, as is well known, is a very abundant metal. It has by chance been found native, but generally exists in the state of a sulphuret, combined with various acids.

The ores of lead are chiefly:

1. Galena, in which it is combined with sulphur, frequently with a portion of silver, and sometimes of antimony or cobalt; and

2. Lead spars, wherein it is combined with sulphuric, phosphoric, molybdic, arsenic, muriatic, carbonic, and chromic acids. One or other of these ores are found in various parts of Europe.

Pure lead may be obtained by solution in nitric acid, and repeated crystallization. The dried nitrate may then be fused with charcoal.

It has a blueish white colour, and considerable lustre; but it soon tarnishes on exposure to the atmosphere. Its specific gravity 11.35.

It is very slowly acted upon by the air, or by water. A thin coat of oxide soon forms on its surface, which appears to defend it from further action.

It may be rolled out into thin sheets, and drawn into wire; but it is a soft metal, and its tenacity is slight.

It fuses at about 600°, and if exposed to the air in this state, it becomes rapidly oxidated. Exposed to a strong heat, it boils and fumes; consequently, it evaporates.

It is brittle at the instant of solidification, and then shews a fibrous crystalline texture.

§ 2. Lead is capable of combining with three proportions of oxygen.

The *Protoxide* is obtained by decomposing nitrate of lead with potassa or soda, or by exposing it to a strong heat without the access of oxygen.

It is of a pale yellow colour, insipid, and insoluble. It is fusible, and on cooling falls into irregular, semipellucid, crystalline, salmon-coloured scales, which are slightly volatile at a bright red heat.

When in fusion, it promotes the oxidation of most other metals, and combines with their oxides. In consequence of this property, arises its use in cupellation, or refining of gold and silver.

It consits of 1 atom of lead 104, + 1 atom of oxygen 8; = 112.

It is known in commerce by the names of litharge, and massicot; according to its state of aggregation.

Deutoxide of Lead is formed by exposing the protoxide, in a reverberatory furnace, to heat; with a very free access of air, and raising the heat to a certain extent for about forty-eight hours.

This is known by the name of red-lead, and consists of lead 1 atom 104, + oxygen 1½ atom 12; = 116.

A deutoxide of lead is sometimes found native.

When red-lead, or minium, as it is sometimes called, is exposed to the action of nitric acid, a decomposition is produced. A part of the lead becomes a protoxide, and is dissolved by the nitric acid; while its oxygen combines with the remaining part of the lead, and converts it into a peroxide, which is an insoluble brown substance. It appears to consist of lead 1 atom 104, + oxygen 2 atoms 16; = 120.

The Peroxide of Lead is insoluble in nitric acid.

If the deutoxide or peroxide are exposed to a strong heat, they part with oxygen, and are converted into a yellow oxide.

Water has no action on lead, but with the help of air it is capable of dissolving and holding in solution a minute portion of its oxide. Delicate analysis has traced the presence of lead in water, which has passed through a

distance in pipes of this metal; and its presence has visibly affected the health of persons who have used such water for a length of time.

Lead is perhaps the most dangerous of poisons; for minute doses of it may easily be swallowed daily unperceived, and may produce very serious, and even fatal effects; especially in persons who were previously invalids, without the cause being suspected, or perhaps suspected when too late.

It should be recollected that waters, as they flow naturally, are scarcely ever free from some saline admixture, that will promote the oxidation of lead, and the action of water on its oxides. Water, therefore, which is intended to be used in food, should not be kept in cisterns of lead, nor be allowed to pass any considerable distance through pipes of it.

§ 3. *Chloride of Lead* may be produced by burning lead in chlorine gas: when a little heated it takes fire and burns with a clear sparkling white flame.

It is readily prepared also, by decomposing any soluble salt of lead with common salt; a muriate of lead is precipitated, which, when dried and fused, becomes a chloride.

It is volatile in the open air, at a bright red heat. It appears to consist of lead 1 atom 104, + chlorine 1 atom 36; = 140.

It is fusible, and on cooling it has that appearance and texture which strongly resembles horn.

It is soluble in 22 parts of water at 60°; being then converted into a muriate. It is more soluble in hot water, and if cooled slowly, the extra portion of salt separates in small acicular crystals of a sweetish taste, and unalterable in the air.

When two parts of red oxide of lead, and one of muriate

of soda, are made into a paste with water, an action takes place, the soda is disengaged, and a compound formed, which appears to be a subchloride of lead. When fused, it produces the heavy bright yellow pigment called patent yellow.

A native chloride of lead is sometimes met with in crystals of a greenish yellow colour.

Chlorate of Lead is in sweetish crystalline flakes.

Iodide and iodate of lead, are insoluble. The alkaline hydriodates are among the most delicate, and characteristic tests of lead; which they throw down, in the state of an iodide of a bright yellow colour.

A nitrate and a subnitrate of lead may be produced.

§ 4. Nitrate of lead is obtained by dissolving the metal slowly, in due proportion, in diluted nitric acid. By evaporation pearly tetraedral and octoedral prisms are produced, which are sweetish, and soluble in less than eight parts of boiling water.

It consists of protoxide of lead 1 atom 112, + nitric acid 1 atom 54; = 166.

If the lead be added in excess to the nitric acid, and heat applied, a subnitrate of lead is produced, which should be filtered while hot.

It consists of protoxide of lead 2 atoms 224, + nitric acid 1 atom 54; = 278.

§ 5. *Carbonate of Lead* may be obtained by decomposing nitrate of lead, with an alkaline carbonate. It is more generally, and economically, prepared in large quantities by the intervention of the vapour of acetic acid, or vinegar, which is decomposed during the process. This is the ceruse or white lead of commerce, so extensively used as a white paint.

It consists of protoxide of lead 1 atom 112, + carbonic acid 1 atom 22; = 134.

§ 6. *Sulphuret of Lead* may be produced by melting the ingredients together in proper proportions. It has the appearance of metallic lead, but is very brittle.

It is met with native in great abundance, and is known by the name galena.

The ore is washed, roasted in a reverberatory furnace, fused, and cast into pigs.

Sulphuretted hydrogen, or the alkaline hydrosulphurets, decompose solutions of lead. A black hydrosulphuretted oxide falls down.

A fresh-made solution of an alkaline sulphuret is one of the best tests of the admixture of lead in urine, or any other fluid.

Lead combines with hyposulphurous and sulphurous acids.

§ 7. Sulphuric acid does not act upon metallic lead unless it be concentrated and hot. A part of the acid then is converted into sulphurous acid and escapes; the metal becomes a protoxide, and combines with the sulphuric acid, producing an insoluble white compound, consisting of protoxide of lead 1 atom 112, + sulphuric acid 1 atom 40; = 152. When dried at the temperature of about 400°, it may be heated to a bright red heat without further loss of weight. Heated with charcoal the sulphuric acid is decomposed, as well as the oxide, and a sulphuret produced. It is insoluble in nitric acid, but is sparingly soluble in dilute sulphuric acid; from which it falls down in small prismatic crystals.

A native sulphate is met with in Scotland, and in Anglesea.

Sulphate of lead is sometimes produced in chemical analyses; it is, therefore, important to know its precise composition.

§ 8. Phosphorus and its acids may be combined with lead, but the compounds produced are of no importance.

A native phosphate of lead has been met with in Cumber-

land, Durham, Yorkshire, and in Scotland. It is sometimes crystallized in six-sided prisms. It is semi-pellucid, and brittle.

Fluate of lead is nearly insoluble in water, and fuses into a yellow mass when heated.

The soluble salts of lead have a sweetish taste. They are precipitated white by sulphuric acid, alkaline sulphates, and by ferrocyanate of potassa; very deep brown by sulphuretted hydrogen and hydrosulphuret of ammonia, and yellow by hydriodate of potassa. Those salts of lead which are insoluble in water, are soluble when heated in soda or potassa, and may be reduced by fusing with charcoal. Chromate of lead is a beautiful reddish yellow paint.

Lead is precipitated from most of its combinations with acids by zinc or tin.

Fat oils combine with oxide of lead, forming an imperfect soap, known by the name of diachylon plaster.

Lead alloyed with tin forms common pewter and solder. Alloyed with copper, it forms what is called pot-metal.

Lead, when melted, readily dissolves gold and silver at a low red heat, as well as copper, and some other metals.

The uses of lead are very extensive. The British consumption of it appears to amount to 48,000 tons annually, upon an average.

On account of its poisonous property, which in some cases operates slowly, for a length of time, unsuspected, and almost imperceptibly, it should never be employed for spoons or any kind of culinary utensil.

Article 6. Tin.

§ 1. Tin exists in great abundance in Cornwall, from whence it appears to have been collected from the earliest ages. It is found in Gallicia also, and in the circle of Erzegeberg in Saxony, in India, and in America. It occurs

in the state of oxide, combined with more or less of iron, and also combined with sulphur.

In commerce it occurs in the state of grain tin, or tin in blocks; and is usually prepared from its native oxide, by heating it with charcoal. It is of a silver colour, and susceptible of a bright lustre, which is slightly tarnished by exposure to air. It is a softish metal, little tenacious, bends harshly with a peculiar noise, is almost inelastic, and scarcely sonorous. It is malleable: tin-foil may be extended to one two-thousandth part of an inch in thickness.

Its equivalent is rated at 59. Its specific gravity is about 7.9.

In the common temperature, it is little affected by air or water. If ignited in oxygen gas, it burns freely. It becomes brittle when heated, and may readily be shaken into a granular powder by agitation, as it cools from a fused state. When broken while hot, it shews a fibrous grain.

It is fused at about 440°, and by a continuance of the heat, while exposed to atmospheric air, it may be converted into a grey powder, which is the protoxide.

§ 2. *The Protoxide* may be obtained also by the precipitation of protomuriate of tin with ammonia. It is of a grey colour, and not altered by heat in close vessels. It is soluble in alkalies, and the solution, by long keeping in a close vessel, separates into metallic crystals, and a solution of the peroxide.

This oxide, at a bright red heat, takes fire, and combining with an additional portion of oxygen, becomes a peroxide.

Peroxide of Tin is produced by burning tin or its protoxide in a strong red heat, or by projecting nitre upon the metal in fusion. This oxide, when exposed to a strong heat, loses a part of its oxygen, fuses, and becomes vitreous, and insoluble in acids. When fresh precipitated, in the state of an hydrate, it is soluble in muriatic acid. It is

very difficult to fuse, but melts with glass into a white opaque enamel.

The composition of the oxides of tin appears to be, protoxide, 1 atom 59 tin, + 1 atom 8 oxygen; = 67; peroxide, 1 atom 59 tin; + 2 atoms 16 oxygen; = 75.

The oxides of tin are soluble in the alkalies, and are precipitated by the carbonic and other weak acids. The alkalies precipitate the solutions of tin, in the state of hydrated oxides.

§ 3. *Protochloride of Tin* is produced by exposing to heat a protomuriate of tin until it fuses, or by heating an amalgam of tin and mercury with calomel. It is a semi-transparent solid, which is volatile at a red heat. It consists of tin 1 atom 59, + chlorine 1 atom 36; = 95.

The addition of water converts it into a protomuriate.

Perchloride of Tin is obtained by burning tin in chlorine, or by making an amalgam of six parts of tin and one of mercury, and mixing this intimately with thirty parts of corrosive sublimate. It must then be distilled in a glass retort with a large receiver, by a heat cautiously raised.

A volatile liquid is produced, which evolves dense white fumes on exposure to air. Towards the end of the process, its consistence is more thick, and hence it was called butter of tin by the older chemists; by whom also the liquid was named, "fuming liquor of Libavius."

This compound is free from water, and has so strong an affinity for it, that its vapour attracts and condenses the hygrometric moisture of the air, producing the dense fumes for which it is remarkable.

A small proportion of water converts it into a solid crystalline permuriate, a part of the water undergoing decomposition.

It is decomposed by zinc; tin is separated in the metallic state, and chloride of zinc produced.

It consists of tin 1 atom 59, + chlorine 2 atoms 72; = 131.

Two oxides of tin combine with muriatic acid.

The protomuriate is obtained by boiling one part of tin with three of muriatic acid. It consists of tin protoxide 1 atom 67, + muriatic acid 1 atom 37 ; = 104.

The solution is acid, and crystallizes in small deliquescent needles. If exposed to the air, it attracts oxygen with considerable energy, and a peroxide precipitates. It is, in consequence, sometimes applied to eudiometrical purposes. It attracts oxygen from peroxide of iron, leaving it in the state of a protoxide. In the same manner, it partially deoxidizes several other metallic salts. Those oxides, the metals of which have a slight attraction for oxygen, it decomposes. With a solution of gold, it produces a purple precipitate, known to the old chemists by the name of purple powder of Cassius, which is used for its colour in enamel painting, &c.

It gives a black precipitate with hydrosulphurets. It precipitates infusion of cochineal of a purple colour.

A *Submuriate* may be procured by precipitating this salt with potassa. It appears to consist of protoxide 2 atoms, 134, + muriatic acid 1 atom 37 ; = 171.

When the protomuriate of tin is exposed for a time to the atmosphere, or when tin is dissolved in nitro-muriatic acid, a permuriate of tin is produced. It is produced also by the addition of water to the bichloride, caloric being excited. It does not precipitate metallic solutions. It produces a beautiful scarlet colour with infusion of cochineal, and, with some modification, is used for this purpose by dyers for dyeing scarlet. The oxides of tin are both soluble in alkalies, the peroxide more so than the protoxide.

§ 4. *Nitrate of Tin* is produced by exposing the metal to dilute nitric acid. The greater part of the metal is merely oxidated. A yellow uncrystallizable solution is obtained, which by exposure to the air is gradually decomposed. A peroxide falls down, a part of the water and of the acid are

decomposed, ammonia is produced, and combines with a part of the remaining acid.

§ 5. Carbonate of potassa, when added to a protomuriate, is decomposed, and an insoluble white carbonate falls down, which is decomposed, by any acid, with effervescence.

§ 6. Tin combines with sulphur in two proportions.

A Sulphuret is produced by the decomposition of the bisulphuret; or by exposing tin and sulphur in due proportions to a high temperature, in close vessels. It is of a blueish colour, and lamellated, or it crystallizes in needles. It consists of tin 1 atom 59, + sulphur 1 atom 16; = 75.

The Bisulphuret of Tin is formed by exposing tin to the action of a sufficient quantity of sulphur at a high temperature.

There is some difficulty in obtaining this sulphuret; for the two bodies combine at a very high temperature only; and when exposed directly to a sufficient heat, a great part of the sulphur escapes, before the combination can be produced.

The following formula is one of the best for procuring it.

Amalgamate 12oz. of tin with 6oz. of mercury. Mix the amalgam thoroughly with 7oz. of sulphur and 6oz. of sal ammoniac; and put it into a glass matrass, placed in a sand bath; apply a gentle heat until it ceases to send forth fumes, then raise the heat to redness, and keep it so for some time. When cold, the bisulphuret, known in commerce under the name of mosaic gold, may be taken out.

The composition of this body appears to be tin 1 atom 59, + sulphur 2 atoms 32; = 91.

It is a soft flaky substance, of a brilliant gold colour. It is used as a pigment, chiefly by japanners. It is known under the name of mosaic gold.

An intermediate sulphuret appears to have been produced by M. Berzelius, of a greyish colour and metallic lustre.

Tin is capable of combining with the different acids of sulphur; with phosphorus also, and its acids; but the compounds are not applied to any use.

Fluate of protoxide of tin, crystallizes in white shining opaque prisms, which absorb oxygen when exposed to the air.

The saline compounds of tin are precipitated white by ferrocyanate of potassa.

Hydrosulphuret of potassa produces a dark brown with the protoxide; with the peroxide a gold yellow.

Corrosive sublimate throws down the protoxide black; the peroxide white.

Muriate of gold produces a purple precipitate with the protoxide.

§ 7. Tin is extensively used; upwards of 3000 tons are annually smelted in Britain. It enters into the composition of several useful alloys. It forms the principal part of pewter. The finest kinds are chiefly tin and wholly free from lead. Amalgamated with mercury it is employed for the silvering, as it is called, of glass mirrors. Plumbers' solder is a compound of equal parts of tin and lead. Bell-metal, and bronze, are compounds of tin with different proportions of copper. Tin-plate is an alloy of iron with tin, produced by keeping the plates of iron, previously cleaned from any oxide, for a certain time in melted tin. The tin during the immersion combines with iron to a certain depth.

It is used also alloyed with a little lead to form a thin covering over the inner surface of copper cooking utensils. The surface to be tinned is scoured bright with sand; it is further cleaned with muriate of ammonia, and then rubbed over with the melted tin; a very thin layer of which adheres to the metallic surface of the copper.

Article 7. Copper.

§ 1. Copper is a metal which is sometimes found native in the metallic state; but it occurs chiefly, and in great abundance, in different states of combination. It is found in various parts of the world, in Cornwall and Anglesea in great quantity; in Germany also, in Russia, and in America; sometimes in the state of an oxide, sometimes combined with sulphur, silica, iron, arsenic, antimony, mercury, and other metallic oxides; sometimes in the state of a sulphate, a phosphate, a submuriate. These ores are found variously, amorphous, or crystallized; and variously coloured, green, blue, yellow, red, and black. Carbonate of copper is also met with. Melachite occurs of various shades of green. Crysocolla, mountain-green, and mountain-blue, are chiefly carbonates of copper.

To obtain copper perfectly pure dissolve the metal of commerce in muriatic acid, dilute the solution and immerse a plate of iron; the copper will be precipitated in the metallic state. To separate any adhering iron, it should be washed with diluted sulphuric acid, and afterwards with water. It is then pure copper, and may be fused if requisite.

That copper is a hard sonorous metal, has a peculiar red colour, is capable of great brilliancy, and is both malleable and ductile, is very well known. It may be drawn into fine wire, and as instanced in Dutch-gold may be rolled into very thin leaves.

Dutch gold contains a certain proportion of zinc, and is about one 60,000 of an inch in thickness.

Copper fuses at a bright cherry red heat, and when the heat is raised to whiteness it slowly evaporates, and burns with a visible vapour. Its specific gravity is when cast, about 8.5, when hammered, nearly 9. When rubbed while

warm, it emits a peculiar slight smell. It is slowly tarnished by exposure to air; and a coat of dark oxide defends it from further action. It does not decompose water at any heat.

A plate of copper heated for a short time in an open fire becomes iridescent on the surface, and at length covered with an oxide, which on hammering it, breaks off in hardish scales. When heated red hot and plunged into water, similar scales are produced.

§ 2. Copper produces two oxides.

The *Protoxide* is best produced by digesting a mixture of the metal and its peroxide in muriatic acid. Potassa precipitates from this a hydrated protoxide of an orange colour. When quickly dried in a close vessel, it becomes of a red brown.

It consists of copper 1 atom 64, + oxygen 1 atom 8; = 72.

The native protoxide is of a ruby colour, or of a steel grey.

The protoxide does not readily combine with acids.

Peroxide of Copper is obtained by decomposing nitrate of copper with carbonate of potassa, and igniting the precipitate: or, by igniting the nitrate of copper or the acetate, or the scaly oxide just spoken of for some time in the air.

It is a black powder, consisting of copper 1 atom 64, + oxygen 2 atoms 16; = 80.

If exposed in hydrogen, part of its oxygen is attracted and water produced. If heated a little above redness and poured into hydrogen gas, it is decomposed with incandescence.

When nitrate of copper is decomposed by pure potassa, a blue hydrated peroxide falls down, which retains its colour when dried at a low temperature. If this hydrate be dried at a higher temperature, it loses about one-fourth of its weight, parting with the whole of its water.

§ 3. Chlorine combines with copper-leaf with great

energy producing inflammation. They combine in two proportions.

The *Protochloride* of copper is a fixed body, and was first described under the name of resin of copper. It may be obtained by exposing copper filings in excess to chlorine, or by drying protomuriate of copper, and heating it nearly to a red heat in close vessels. It is insoluble in water, but soluble in muriatic acid, from which potassa throws down a protoxide. Water precipitates it from its muriatic solution unaltered. Generally it is of a dark brown colour; but if fused and cooled slowly, it is yellow, translucent, and crystalline.

It consists of copper 1 atom 64, + chlorine 1 atom 36; = 100.

The *Perchloride* is best produced by evaporating a solution of the peroxide in muriatic acid, at a heat not exceeding 400°. It is of a yellow colour. On the addition of water it is converted into a permuriate. Exposed to a red heat in close vessels, chlorine is expelled and a protochloride left.

It consists of copper 1 atom 64, + chlorine 2 atoms 72; = 136.

Permuriate of copper is readily formed by dissolving peroxide of copper in muriatic acid. It produces a green solution.

When copper is exposed sparingly to the action of muriatic acid, or when its oxide is added to a permuriate, a green powder is formed, which is a subper-muriate.

This compound is sometimes met with native. A specimen examined by Dr. Davy, produced peroxide 73, muriatic acid 16.2, water 10.8.

§ 4. *Chlorate of Copper* is deliquescent, and difficult to crystallize. It is of a blueish green colour. A piece of paper dipped into this solution, and dried, burns with a beautiful green flame.

§ 5. *Nitrate* or *Pernitrate of Copper* is formed by digesting copper with nitric acid, diluted with three parts of water. The action is very violent, the copper is peroxidized at the expense of a part of the acid; and, in consequence, a large quantity of nitrous gas is evolved, which holds a little copper in solution, while a part of the oxide is precipitated. The liquid solution on evaporation, affords prismatic crystals of a bright blue colour, and very caustic, consisting of peroxide of copper 42.6, nitric acid 57.4, exclusive of water, of which they contain a large proportion, and are liquid in it below 212°. At a higher temperature the water evaporates, and the acid gradually escapes, or is decomposed.

A subpernitrate of copper may be produced by the slow addition of an alkali to a solution of the nitrate.

It consists, according to M. Berzelius, of peroxide of copper 66, nitric acid 18.9, water 15.1.

When nitrate of copper, in coarse powder, is spread upon tin-foil, sprinkled with water, and rolled up in it, so energetic an action is produced, that great heat is excited, and soon a flame bursts out.

§ 6. The oxides of copper are soluble in ammonia.

The protoxide dissolves in a solution of ammonia, and forms, if the operation is carried on in a close vessel, a colourless solution. If the solution be effected in the open air, it rapidly absorbs oxygen, and becomes a solution of the peroxide.

Peroxide of copper dissolves in ammonia, producing a beautiful deep blue ammoniuret. The chemist frequently separates oxide of copper from other metallic oxides, by means of ammonia.

Ammonia added to the nitrate of copper, precipitates the peroxide; an additional quantity redissolves the precipitate, and an ammonia-nitrate is produced.

Copper-plates, macerated in a solution of muriate of am-

monia, become incrusted with a green powder, which is occasionally scraped off, washed, and used as a pigment.

§ 7. *Carbonate of Copper* is prepared by decomposing sulphate of copper with carbonate of potassa. It is a green insoluble powder, consisting of peroxide 1 atom 80, carbonic acid 1 atom 22, + water 1 atom 9; = 111.

When copper is left exposed for a length of time to the air, it becomes incrusted with this compound.

It is used as a pigment, the colour is improved by repeated washing in boiling water.

A beautiful blue pigment, called refiner's verditer, is principally prepared by refiners.

According to Mr. Philips, it consists of peroxide of copper 3 atoms, carbonic acid 4 atoms, water 2 atoms.

§ 8. Copper combines with sulphur in at least two proportions.

When three parts of copper filings, and one of sulphur are mixed and heated, on the fusion of the sulphur an energetic action takes place; a brilliant combustion is excited, and some hydrogen gas escapes.

A black brittle compound is produced, consisting of copper 1 atom 64, + sulphur 1 atom 16; = 80.

This is the *Protosulphuret of Copper*. It is met with native in various places. It is usually of a grey colour, and has a shining metallic lustre.

The persulphuret exists native in great abundance in England, in Cornwall and in Anglesea, and in various other places. It is named, from its colour, yellow copper pyrites. The greater part of the copper of commerce is produced from it. It has not been artificially produced.

The following is an outline of the process of reducing it.

The ore is picked, broken, and heated in a reverberatory furnace, to drive off the arsenic and sulphur. Then it is fused in a smaller furnace, and the slag, as it separates,

is removed, and cast into bricks. The fluid metal is run into water, by which it is granulated. It is melted and granulated two or three times over, by which it is further purified. It is then cast into pigs. These are carried to the refining furnace, where they are broken up again, and melted with charcoal, in which operation some nicety is requisite.

The copper is thus rendered malleable, rolled into plates, and annealed.

§ 9. *Hyposulphite of Copper* is colourless, and if air be excluded, is not turned blue by the addition of ammonia. It has an intensely sweet taste.

Sulphite of copper consists of the protoxide and sulphurous acid. It produces small red crystals.

When nitrate of copper is added to the sulphite of potassa, red crystals of sulphite of copper are produced, and these are intermingled with yellow crystals, which consist of a double salt, a sulphite of potassa, and copper.

§ 10. *Sulphate of Copper*, blue or Roman vitriol. It is a sulphate of the peroxide, and may be prepared by dissolving the peroxide in sulphuric acid. When the protoxide is used, a sulphate of the peroxide is obtained, a part of the copper being reduced.

It is prepared as an article of commerce, in a much more economical way, by exposing the sulphuret previously broken up and roasted, to the action of air and moisture.

According to M. Clement (Ann. de Chimie,) in the preparation of the solution for obtaining the persulphate of copper from the sulphuret, a portion of the proto-sulphate, and subsulphate are formed in the muddy solution. When it is left to settle in wooden tubs, the proto-sulphate becomes decomposed, a part of it becomes a persulphate, and a part of the metallic copper crystallizes upon the sides of

the tubs, in brilliant crystalline mamellæ, having numerous minute facets, of a texture as firm as fused copper.

Persulphate of copper crystallizes in rhomboidal prisms, of a very fine blue colour, consisting of peroxide 1 atom 80, + sulphuric acid 2 atoms 80; = 160, + water 10 atoms 90; = 250.

It is soluble in four parts of water at 60°.

When heated, the water of crystallization escapes, and as the temperature is raised, the sulphuric acid separates undecomposed, the pure peroxide remaining.

By the slow addition of ammonia to a solution of this salt, a subsulphate of copper is precipitated, containing peroxide of copper 2 atoms 160, + sulphuric acid 1 atom 40; = 200.

Three parts of the sesquicarbonate of ammonia, added to two parts of sulphate of copper, form the sulphate of ammonia and copper, which is named cuprum ammoniatum in the London Pharmacopœia.

Sulphate of copper and potassa is a double salt, formed by exposing peroxide of copper to the action of bisulphate of potassa. Its crystals are rhomboids of a pale blue colour.

§ 11. Phosphorus with copper forms a brittle useless sulphuret.

Perphosphate of copper may be produced by mixing sulphate of copper with phosphate of soda. It is a blue green powder, consisting of peroxide 1 atom 80, phosphoric acid 2 atoms 56, + water 1 atom 9; = 145.

A subperphosphate of copper has been met with native, of an emerald green colour, and consisting of peroxide 1 atom 80, phosphoric acid 1 atom 28, + water 2 atoms 18; = 126.

Ferrocyanate of copper has been recommended by M. Hatchett, as a beautiful brown pigment.

Fluate of protoxide of copper is of a red colour, and be

comes darker on applying heat. It decomposes in the air.

Fluate of the peroxide, is of a light blue colour.

The saline compounds of copper are for the most part soluble in water, and of a blue or green colour.

Ammonia produces, with copper, a very deep blue compound; and is a most delicate test of copper.

Ferrocyanate of potassa is recommended by Mr. Brand as the most delicate of the tests of this metal.

Hydrosulphuret of ammonia, produces a black precipitate. A plate of polished iron immersed in a compound containing copper, generally precipitates it in a metallic state.

§ 12. Copper is very extensively used in various arts, and for various domestic articles of furniture. It is the basis of numerous pigments. Verdigris is an acetate of copper; Brunswick green, a subammonio-muriate; verditer, a carbonate.

Not less than 2000 tons are said to be used annually in Birmingham. Its poisonous property ought to forbid its use in the fabrication of cooking vessels.

Several alloys of copper are used in the arts. Brass is an alloy of copper and zinc. To obtain it, granulated copper is mixed with calamine, a carbonate of zinc containing from 12 to 18 per cent. of the metal, and charcoal, and exposed to heat. As the zinc is converted into vapour, it is attracted by the copper.

Brass is less liable to be acted on by the air, or by bodies floating in it, than copper is. It is safer than copper as a culinary utensil in those few cases, where tin, iron, silver, or earthenware cannot be employed.

Bell-metal and bronze, are alloys of copper and tin. They are harder, more fusible, and less malleable, than copper. Bell-metal is generally composed of 3 parts of copper to 1 of tin. Bronze generally contains from 8 to 12 per cent of tin. Before the knowledge of iron, a bronze

containing from 8 to 16 per cent. of tin, appears to have formed both offensive and defensive weapons. It is still used for cannon, as well as for bells, statues, and various ornaments. For small bells, a little zinc is in general added.

Gold is alloyed with copper, both for manufactures and for coin. It communicates a degree of hardness which renders it more durable, without injury to the colour.

The standard gold of England contains one-twelfth of alloy of copper, or of copper and silver. Silver also is alloyed with it for the same purpose, to render it more durable.

Chinese tutenag, or white copper, appears to be a native alloy of copper, zinc, iron, and nickel.

A small quantity of malleable white copper is produced in Germany, which appears to be copper with about 8 per cent. of nickel.

Copper alloyed with a fourth of lead, forms pot-metal. Various proportions of zinc and copper, constitute Prince Rupert's metal, pinchbeck, and Dutch gold.

Manheim gold consists of 1 part of zinc to 3 of copper.

Metals for speculums, consist of 1 part of copper, 2 of tin, and 1 of arsenic.

Article 8. Iron.

§ 1. Iron is one of the most abundant bodies in nature. It is found in most parts of the world, and in various states and combinations.

It is rarely found in a metallic state, except in meteoric stones.

These singular bodies are met with in all parts of the world. There are undoubted and repeated instances of their descent from the heavens, in a state of ignition and combustion; but whence they come is unknown. They consist chiefly of iron in the metallic state, but partially

oxidated, apparently in its passage through the atmosphere, combined with from 1 to 10, or even by chance, 15 per cent. of nickel, and a small proportion of chrome. Other metals are occasionally present.

Iron is found in great abundance in the state of a protoxide in some ores, when they are dark coloured and magnetic; and also in the state of peroxide. At times, the oxides are nearly pure; at others, united with more or less of silica, alumina, lime, oxide of manganese, and other bodies.

It occurs abundantly, combined with sulphur, in the various pyrites. It is met with also, combined with sulphuric, carbonic, chromic, arsenic, and phosphoric acids. Besides, it is combined in smaller proportion with, and gives colour to a great variety of earthy boles, clays, crystallized minerals, &c.

The mode in which the metal is obtained in the different iron-works, varies; depending, of course, on the nature of its combinations. The ores worked for obtaining iron, are not always the richest; the vicinity of fuel is an essential consideration. The ore worked in England, generally contains less than 40 per cent. of metal.

The metal is generally reduced by smelting the ore with charcoal for particular purposes; but more generally in this country, with coal or coke; and care is taken to procure such coal or coke as is free from sulphur, and as free as possible from other impurities.

The fused, or cast-iron thus obtained, is purified by stirring it while in fusion, to burn off the carbon, sulphur, and other impurities, and when it becomes in a semi-solid viscid state, it is exposed to pressure which squeezes out a large proportion of the foreign matter. After these processes have been repeated, it is forged and rendered malleable; and its malleability, purity, and consequent toughness is increased by repeated forging.

The comparatively easy fusion of cast-iron depends upon its foreign admixture.

Iron is produced in such immense abundance, and at so low a rate, that it is not possible to render it free from all foreign bodies. The impurities differ in different places. The consequence is, that the iron produced at different works, varies in quality; and is found best adapted to certain purposes only, and unfit for others.

It is first produced in the state of cast-iron; the varieties of which are chiefly distinguished into grey and white. The white is most hard and brittle; the grey is rather purer, softer, less brittle, and is capable of being cut and turned in a lathe. When cast-iron is acted on by an acid, a large quantity of black, insoluble matter is left; consisting of carbon, silica, oxygen, lime, and often phosphorus and sulphur, more or less oxidized.

Iron appears to crystallize in cubes and in octaedrons, which, on account of its extreme infusibility, hardness, and toughness of texture, it is by no means easy to demonstrate.

By slow solution in a diluted acid, as first practised by Mr. Daniel, a piece of forged iron gives the appearance of fibres extending throughout its length. Native iron, according to Dr. Wollaston, is disposed to break as if composed of tetraedral, and other regular geometrical forms, consequent apparently upon a degree of oxidation, extending in the direction of its crystalline surfaces. It is found in an apparently crystallized state, in the bottom of old smelting furnaces.

A particular kind of Swedish iron is most valued for making steel; another, from its softness, and the fine polish it readily receives, is used for fire-irons; a third kind is most valued for making tin-plate; a fourth for drawing into wire; and others have their peculiar value for different purposes. These varieties appear to depend upon its being variously alloyed with the bases of charcoal, and of the different

earths, with phosphorus, with manganese, and occasionally with other metals.

Very pure iron is softer, more ductile, whiter, and admits of a brighter polish than most of the iron of commerce.

It is very malleable and tenacious, but does not admit of being rolled into thin flexible leaves. It is extremely ductile, and may be drawn out in wire, often to $\frac{1}{150}$ of an inch in diameter. Its tenacity is such that a wire of $\frac{1}{17}$ of an inch in diameter will hold nearly 550 pounds weight. Its specific gravity is from 7.6 to 7.8.

It is perhaps one of the most infusible of the metals; but at a white heat it is in a very soft state, and then is susceptible of being welded, or completely united to another piece at the same temperature, by hammering, or by great pressure.

§ 2. Iron appears to combine with oxygen in two definite proportions, at least.

Polished iron does not appear to be acted upon by dry air. But when the air is loaded with hygrometric moisture, upon a slight depression of temperature, it is condensed on the surface of polished iron; when the iron decomposes it, and becomes rusty. At a high temperature, iron and oxygen combine rapidly. If a watch-spring, or even a steel file one-quarter of an inch thick, be ignited at one end; by means of a bit of burning phosphorus, or by any other way, to a white heat in oxygen gas; it will burn wholly away with great brilliancy, and vivid scintillations. It is the combustion of iron filings that produces the most brilliant of the sparks observed in fire-works.

It is said, that iron does not decompose water, which is wholly free from air. If this should be strictly true, it cannot be applied to practice. The joint action of the two, in rusting iron, is very powerful as is well known.

The Protoxide of Iron is best obtained by precipitating a solution of the green sulphate of iron by potassa, washing,

it with water, deprived of air and drying it at a red heat, in a close vessel.

It consists of iron 1 atom 28, + oxygen 1 atom 8; = 36. When fresh precipitated, it is sparingly soluble in ammonia, and in carbonated alkalies. This same oxide is obtained when iron is burnt in oxygen, or when iron-filings, moistened with water, are exposed to the air for a few days only, the oxide washed out, and dried speedily in a close vessel, or when steam is decomposed by it at a red heat. The scales produced at the blacksmith's forge are a protoxide. It is a black insoluble insipid substance.

When iron filings, or the protoxide, are boiled slowly in nitrous acid in an open vessel, precipitated by ammonia, and exposed to a dull red heat, a red, or *peroxide of iron* is produced.

It appears to consist of iron 1 atom 28, + oxygen 1½ atom 12; = 40.

Colcothar of vitriol, when it has been exposed to a bright red heat in an open vessel, is this oxide.

M. Gay-Lussac thinks that a definite oxide exists, consisting of 100 of iron to 38 of oxygen nearly. M. Thenard too, thinks that this deutoxide is existing in the magnetic iron ores. It may however be a mixture of the two oxides before spoken of.

M. Thenard contends also for another oxide with less oxygen than that named above as a protoxide; with 25 for instance, to 100 of metal.

When 100 parts of iron are dissolved in diluted sulphuric acid, they liberate 170 cubic inches of hydrogen gas, and consequently have combined with 85 cubic inches of oxygen; those being the proportions which constitute the water decomposed. Now this 85 cubic inches of oxygen will weigh 28.8 grains, nearly. This experiment would at first appear to be conclusive; but it is extremely difficult to get metal-

lic iron that is free from all alloy, and at the same time free from oxide; and the results of different experiments have not been uniform. M. Gay-Lussac states the quantity of oxygen combined with iron, as verified by this test to be only 25 grains, as well as by decomposing the protosulphate with potassa, or soda, and drying the precipitate in close vessels. This subject therefore requires further examination.

It has been seen that metallic iron, at a red heat, decomposes water. On the other hand, if hydrogen gas be passed over oxide of iron, at a red heat, it decomposes a part of the oxide.

§ 3. Chlorine forms two compounds with iron. The *protochloride* may be produced by evaporating the protomuriate of iron until dry, in a close vessel; and exposing it to a red heat. A shining, grey, brittle, fusible, fixed body is formed, which may be considered to consist of, iron 1 atom 28, + Chlorine 1 atom 36; = 64.

It burns in chlorine, and produces a bright yellowish brown substance, which is volatile, and condenses in small brilliant iridescent plates, that appear to consist of, iron 1 atom 28, + chlorine 1½ atom 54; = 82.

Protomuriate of iron may be formed, by slowly dissolving clean iron filings in diluted muriatic acid, excluding the air. By evaporating the clear solution in a close vessel, pale green crystals are produced. They have an astringent taste, are very soluble in water, and insoluble in alkohol.

The permuriate is produced by dissolving the peroxide, or red rust of iron, in muriatic acid. A dark red deliquescent astringent mass is produced on evaporation, which is soluble in water, and in alkohol. The protomuriate, if left exposed to the air, becomes a permuriate. If exposed to heat, the permuriate gives off water, muriatic acid, and then chlorine; a portion of chloride of iron sublimes, and a portion of peroxide remains behind.

With iodine, iron forms a compound, decomposable by water.

§ 4 *A Protonitrate of Iron* may be formed by dissolving iron slowly in dilute nitric acid, without access of air. A green solution is produced, not easily crystallizable. It is generally darkened by the presence of nitrous gas, which is evolved during the solution, and retained by it.

If concentrated nitric acid be a little diluted with water, it acts rapidly on iron, evolving a large quantity of nitrous gas. A dark reddish solution is procured, not crystallizable, which is a pernitrate.

§ 5. Carbon may be combined with iron, and produces peculiar compounds.

From one-sixtieth to one one-hundred-and-fortieth of carbon, combining with iron, converts it into steel. The process by which this is accomplished is called cementation. This process consists in packing a number of bars of very fine malleable iron in charcoal, and exposing them to a high temperature during some days. A part of the carbon is converted into vapour, and its base is attracted by the heated iron, and combines chemically with it. The more completely the union is accomplished, and the purer the iron in other respects, the better is the product. It does not appear that the presence of any other body is necessary to produce good steel.

There is a variety of steel produced in India, called wootz, which is particularly valued for fabricating fine cutting instruments. Its value *appears* to be owing to the presence of a minute proportion of the bases of alumina and silica.

Steel has the singular and valuable property of being susceptible of various degrees of hardness or softness, as occasion shall require. When made red hot, if suffered to cool slowly, it remains soft. When cooled suddenly by plunging it into cold water, it becomes extremely hard,

but at the same time very brittle, and it is rendered more hard and brittle as the water is colder. In this state it is too brittle for most uses, and it is found necessary to temper it, or heat it again to a certain point, known by experience, and varying according to the use it is applied to; and suddenly cooling it in cold water as before. By this means, steel instruments are brought to the precise hardness, elasticity, and toughness required. This may be done by heating the metal in hot oil, mercury, or any fusible metallic mixture, varying the heat of the bath by a thermometer according to the temperature required. The workmen usually judge of the temperature by the change of colour consequent upon the degrees of oxidation produced. A very faint change of colour is produced by a heat of 430°, a straw colour appears at 460°, as the temperature rises it gradually becomes deeper, at 500° the colour becomes brown, then reddish, then tinged with purple, and at 600° a fine deep blue, the colour of watch springs, is produced. It has been found that, for some purposes, the heat of 212° gives a proper temperature.

Of the cause of these changes in steel no more is known, than of the cause of solidification in general.

Carbon is one of the principal bodies that gives character to cast-iron, but it exists in cast-iron in very uncertain proportions, and is generally accompanied by other impurities.

Plumbago, graphite, or black-lead, a substance well known, is a native carburet of iron, containing from five to nine per cent. of carbon. It is used for black-lead pencils; to defend and ornament the surface of cast-iron; in the composition of stoves and crucibles; and, mixed with grease, to lessen friction in machinery, and between the wheels and axles of carriages.

§ 6. Iron combines with cyanogen and probably hydrogen; forming a compound, which, on account of its pro-

perty of combining with the metallic oxides, is considered as an acid, and is called ferrocyanic acid.

It may be obtained by precipitating with sulphuric acid, the baryta from the ferrocyanate of baryta, and decanting the clear acid.

It has a pale lemon colour, has no smell, and is not poisonous in small doses. It is decomposed by a strong light, or a gentle heat. It combines with alkalies, earths, and oxides.

The elements of this acid are held together by a slight attractive force, while in its pure state; but it forms durable compounds with alkalies and the metallic oxides, with which it has a strong tendency to combine, forming double salts.

When the pigment, called Prussian blue, is added to a boiling solution of potassa, it is decomposed. When the potassa is saturated, on filtering and evaporating the solution, a double salt is obtained, which consists of cyanogen, or hydrocyanic acid, oxide of iron and potassa, producing ferrocyanate of potassa. It is a permanent compound, which crystallizes in handsome yellow cubical crystals. They have a peculiar taste. By sulphuric acid they are decomposed; hydrocyanic acid is produced, and protoxide of iron precipitated.

In the same manner may be produced ferrocyanates of ammonia, soda, lime, magnesia, baryta, and strontia.

Chemists are divided in opinion, whether, in these compounds, the iron is combined as an acid, or a base. Analogy is rather against the opinion of iron existing with the properties of an acid. On the other hand, if it existed as a base, it would probably be decomposed by the usual tests for iron, but it is not.

Prussian Blue is produced when hydrocyanate of potassa is poured into a solution of sulphate of iron. At first the precipitate is whitish, yellow, or green; but it rapidly absorbs oxygen, and becomes of a beautiful blue colour.

It is not acted upon by dilute acids, but is decomposed by the alkalies, which combine with the ferrocyanic acid, and leave the remainder of the iron in the state of oxide.

This pigment is prepared by the manufacturers by heating, to a low red heat, about two parts of carbonate of potash, and five of any animal matter, such as dried blood, hoofs, horn, or flesh, keeping the mixture in constant motion until fetid vapours cease to arise. Six or eight parts of water are then poured over the burnt matter; when cold, the solution is strained off and filtered. Two or more parts of alum, and one part of sulphate of iron, are then mixed with this solution. A precipitate falls down, of a dingy green colour. By washing it with diluted muriatic acid, the foreign matter is removed, and the Prussian blue left of a fine blue colour.

The theory of this process may be thus explained.

The animal matter is decomposed by heat, and its elements combine into other compounds, according to the balance of attractions. Among these, cyanogen is produced, and being immediately attracted by the base of the potassa, forms a cyanuret of potassium, which, when acted upon by water, becomes a hydrocyanate of potassa. It i[illegible] with carbonate of potassa and ammonia. Whe[illegible] tion is added to a solution of common [illegible] iron, an insoluble precipitate is fo[illegible] cyanate of iron, which, in the [illegible] white colour, but gradually [illegible] saturated with oxygen. [illegible] pitated with it, gives [illegible] oxide is removed by [illegible]

of the metals, which appear to be true ferrocyanates of the respective metals, and when heated with potassa, they afford the ferrocyanic acid.

Mr. Porret, who has paid particular attention to this subject, concludes, that these so called ferrocyanates are compounds of a peculiar acid, which he names ferrochyazic acid.

§ 7. *Carbonate of Iron* is produced by decomposing the protosulphate of iron, with carbonate of potassa; a green precipitate falls down, which dries of reddish brown colour.

It appears to consist of protoxide of iron 1 atom 36, + carbonic acid 1 atom 22; = 58, while in a moist state; but the greater part of the carbonic acid escapes with the water in drying, and oxygen is absorbed.

Water, saturated with carbonic acid, acts on iron, and produces a soluble supercarbonate of the protoxide evolving hydrogen gas. On exposure to the atmosphere, the gas escapes, and the iron precipitates in the state of a peroxide.

§ 8. Sulphur and iron combine strongly; in two definite proportions more particularly.

The black, or *Protosulphuret*, is produced by melting to- iron and sulphur; heat is evolved, and a definite rittle compound is produced, consisting of iron hur 1 atom 16; = 44.

tive, and is distinguished by the also procured by rubbing a white hot iron, fresh from a d, and the sulphuret ra-

ly sol in diluted

It consists of iron 1 atom 28, + sulphur 2 atoms 32; = 60.

When iron filings and sulphur are mixed in large quantity, and moistened; after a time heat is evolved, and at length bursts out into incandescence. A mixture of one part of iron, and three of sulphur, when well mixed, and heated in a glass tube, produces a brilliant inflammation. In both cases without the agency of oxygen.

§ 9. *Protosulphate of Iron* is produced by dissolving iron filings, or the protoxide, or a mixture of peroxide and iron in sulphuric acid. The solution produces beautiful green rhombic crystals, having an astringent taste.

They consist of protoxide 1 atom 36, sulphuric acid 1 atom 40, + water 7 atoms 63; = 139.

It reddens some vegetable blues, and turns syrup of violets green. It is soluble in two parts of cold water. If left exposed to air, it absorbs oxygen, and is gradually changed to a peroxide. It absorbs nitrous gas, acquiring a deep brown colour.

When the crystals are heated to nearly a red heat, they lose forty per cent. of water, and form a whitish grey substance, which consists of one atom of dry sulphate, and one atom of water. When the heat is increased, it is decomposed, producing sulphuric acid, some an-hydro-sulphuric acid, and some sulphurous, and a peroxide remains, which is called colcothar of vitriol

This sulphate is generally produced in great quantity, for the use of artists and manufacturers, by the action of oxygen upon the native pyrites; which, for this purpose, is exposed to warmth, air, and moisture, and thus converted into a bipersulphate, which is reduced to the state of a protosulphate, by the addition of old iron hoops, nails, &c. The solution is then boiled down, and crystallized; being at the same time sufficiently defended from the too free action of oxygen.

Persulphate of iron is obtained by dissolving peroxide of iron in sulphuric acid.

It consists, according to Berzelius, of peróxide 1 atom 40, + sulphuric acid 1½ atom 60; = 100. Its taste is astringent.

It appears that a subpersulphate of iron may be produced, and also a bipersulphate, and probably a quadripersulphate. A sulphate of iron and ammonia may be produced.

§ 10. *Phosphuret of Iron* may be formed. It is a brittle grey magnetic compound, often found in cast-iron.

Protophosphate of Iron is formed by decomposing protosulphate of iron with phosphate of soda. It is a pale blue insoluble compound.

The *Perphosphate of Iron* is produced in the same manner from the persulphate. It is an insoluble white compound. A subperphosphate may be formed. It is of a red colour.

The other salts of iron are so numerous and unimportant, that it would be tedious to enumerate them. Those formed from the protoxide are mostly soluble in water, and if left exposed to the atmosphere, they absorb óxygen, and their base becomes a peroxide, and is partly precipitated of a reddish brown colour.

Ferrocyanate of potassa precipitates the protóxide whitish, but it soon absorbs oxygen, and changes to a blue hydrocyanate of the peroxide.

An infusion of galls, or of any astringent vegetable, throws down from the salts of iron, a precipitate of a deep purple or black, or soon becoming so. This precipitate is the basis of ink, and all black dyes.

Alkaline hydrosulphurets produce a dark brown or black grey precipitate. Alkaline phosphates produce a whitish coloured; succinate of ammonia flesh coloured; and benzoate of ammonia a yellow precipitate.

The uses and application of iron and its compounds, in the service of mankind are, as is well known, extremely numerous and extensive. To enumerate and explain them, would alone fill a volume.

Article 9. Of Manganese.

§ 1. This metal has too strong an attraction for oxygen ever to be found native in a metallic state. But it occurs in considerable abundance, combined with oxygen, in the state of peroxide. It is met with also mineralized with iron, for which it shews a strong attraction, and with phosphoric acid, silica, and other bodies, in several parts of England and Europe.

The simplest process for obtaining this metal pure is that recommended by Mr. Faraday, viz. to heat muriate of ammonia with an excess of black oxide of manganese in a crucible. The chlorine disengaged is attracted by the manganese, in preference to any other metal that may be present, on account of their superior attraction for each other; nor does it act upon any other metal until the whole of the manganese is saturated. The addition of water converts the chloride into a soluble muriate, which, when separated, may be decomposed by bicarbonate of potassa, and the carbonic acid may be expelled by heat. Should any iron be present in the solution, it may be previously separated by the addition of ammonia, which forms with the oxide of manganese a soluble double salt. By exposing the oxide thus purified to an intense heat, after being made into a ball with pitch, or charcoal, the metal itself is obtained.

It is of a whitish colour, opaque, and rather bright when first broken, but soon growing dull from a coat of oxide forming on its surface. Its specific gravity is 8. It is very brittle, extremely difficult of fusion, requiring a heat greater than wrought-iron does. When exposed to the air, it absorbs oxygen, and soon falls into a black powder.

§ 2. Chemists are divided in opinion in relation to the number of definite oxides it is capable of forming. Sir H. Davy ascribes two oxides to it; Dr. Forehammer and Mr. Brande, three; Thenard thinks he has discovered four; and M. Berzelius, five. This metal has a very strong attraction for oxygen, and readily passes into the state of a peroxide;, and the question is, whether the different appearances of the saline precipitates, and the different proportions of oxygen they afford, are not the consequence of their being mixtures of two definite oxides with each other, or with different proportions of water.

When a muriate of manganese is precipitated by alkalies, a white precipitate is formed, which is a hydrated protoxide. When dried in a close vessel, it becomes of an olive-green colour, and may be considered as a protoxide.

When the black peroxide is exposed to a red heat, it gives out a large quantity of gas. The reddish brown mass remaining, from which heat can separate no more oxygen, may be considered as a deutoxide of definite composition. If an acid act upon this oxide, it combines with a part of the manganese in the state of a protoxide; the oxygen thus separated combining with the remaining portion into a peroxide.

The peroxide of manganese may be prepared artificially, by leaving either of the above named oxides exposed to the air, or more speedily by treating them with nitric acid.

It is met with in great abundance in several parts of England, and in other parts of the world. Sometimes it is crystallized, having a grey metallic radiated lustre, sometimes in rhomboidal prisms.

Chemists are equally divided relative to the proportions of oxygen they assign to the atom of manganese. The nearest approximation, perhaps, is that of Dr. Thompson, supposing these to be true definite oxides of manganese:

	Manganese.	Oxygen.	
Protoxide	1 atom 28, +	1, 8;	=36
Deutoxide—metal 2 atoms, oxyg. 3, or	1 28, +	1½, 12;	=40
Peroxide	1 28, +	2, 16;	=44

§ 3. When manganese is burnt in chlorine, it inflames, and a pink semi-transparent substance is obtained in deliquescent flakes. Dissolved in water, a muriate of manganese results.

Chloride of manganese is formed also by heating the black oxide in muriate of ammonia.

If muriate of manganese be heated in a close retort, a protochloride is produced; but if heated in an open vessel, the acid is driven off, and the remaining matter is an oxide.

Chloride of manganese appears to consist of manganese 1 atom 28, + chlorine 1 atom 36; = 64.

The muriate of the protoxide may be obtained in rose-coloured tabular deliquescent crystals, consisting of, when freed from water, protoxide of manganese 1 atom 36, + muriatic acid 1 atom 37; = 73.

When muriatic acid is poured upon the peroxide of manganese, they are both decomposed, and a large quantity of chlorine is liberated; the hydrogen combining with a part of the oxygen of the peroxide, converts it into a soluble protoxide, and forms water; the protoxide at the same time dissolving in the remaining muriatic acid, produces a muriate of manganese.

§ 4. Diluted nitric acid dissolves the protoxide of manganese.

When poured upon the deutoxide, a protonitrate is produced, and the oxygen thus separated combines with a part of the deutoxide, forming an insoluble peroxide.

When the acid is poured upon the peroxide, no action follows; but if a little sugar be added, it attracts a part of the oxygen, and a protonitrate is formed.

The nitrate of manganese appears to consist of protoxide of manganese 1 atom 36, + nitric acid 1 atom 54; = 90.

§ 5. *Carbonate of Manganese* is produced by precipitating a saline solution of manganese by an alkaline carbonate. It is a white compound, insoluble in water, and consists of protoxide of manganese 1 atom 36, + carbonic acid 1 atom 22; = 58, exclusive of water.

§ 6. The combinations of manganese with sulphur or sulphuretted hydrogen, or with phosphorus and its acids, are not applied to any use.

Sulphuric acid produces with protoxide of manganese rhomboidal prismatic crystals, which are supposed to consist of protoxide 1 atom 36, + sulphuric acid 1 atom 40, + water 5 atoms 45; = 121.

Fluates of the oxides of manganese are of a red colour, and soluble in water.

Manganese communicates a violet colour to most of its salts.

§ 7. There are reasons to suspect, that in certain combinations manganese unites with other proportions of oxygen. It combines with alkalies or other metallic oxides by fusion. It is used in glass-making, to destroy the colour produced by iron, and other colouring oxides. When added in too large a proportion, it produces a violet colour; when in an intermediate proportion, the colour of the glass remains white, until it is exposed to the light of the sun, and then gradually assumes the violet tint sometimes observed in plate-glass.

An ore of manganese called black wadd, when powdered, dried, and mixed with about a fourth of its weight of an expressed oil, in about half an hour heats, and at length inflames.

When the black oxide is exposed to the heat of the blowpipe, mixed with borax, the exterior flame communicates to it a violet colour, which is destroyed by the interior flame.

When this oxide is powdered with an equal quantity of nitre, and ignited, a compound is obtained, which is remarkable for exhibiting different colours, according to the quantity of water added to it. With a small quantity, it produces a green solution; add a little more, it becomes blue; a further addition produces a purple tint; a still larger quantity produces a beautiful deep purple. Varying the temperature of the water also produces variation of colour; hence this compound is called mineral camelion. If sulphuret of potassa, or any substance having a strong attraction for oxygen, be added, this property is destroyed.

These various changes of colour and appearance are *supposed* by some chemists to arise from the production of manganesous and manganesic acids, and from their forming different compounds with potassa.

The native black, or peroxide of manganese, is much employed in procuring chlorine, both by the bleacher and the chemist. It is employed also to procure oxygen gas, which it gives off in abundance at a red heat, while it is thus reduced to a deutoxide.

It is used also, as has been said, to destroy the colour communicated to glass by iron and other metallic oxides. On account of the colour it gives, it is used in enamel and porcelain painting, and also to give a black colour to the biscuit of earthenware.

Article 10. Cobalt.

§ 1. Cobalt is mostly found in combination with oxygen, sulphur, and arsenic, frequently with iron, copper, nickel, bismuth, and other metals, and sometimes with sulphuric acid. It is met with in England and several other parts of Europe; but it comes chiefly from Germany.

The ore is generally roasted to expel the sulphur and arsenic, and then ignited with charcoal, when it produces the cobalt ore of commerce.

To obtain the pure metal reduce the cobalt ore of commerce to powder, and mix it with four parts of nitre, calcine it and wash the mass in hot water. Repeat this operation three or four times to separate the arsenic it is combined with. Dissolve in dilute nitric acid; a plate of iron immersed will separate the copper when present; then filter and evaporate to dryness. Digest the dry mass again in diluted nitric acid. A solution of potassa will then precipitate the oxide of cobalt, and it may be reduced to the metallic state by fusing it with black flux or charcoal. It is difficult to separate nickel from it.

Pure cobalt is of a pinkish grey colour, brittle, easily powdered, and fusible at an intense heat.

When cooled slowly it crystallizes in irregular prisms. It is magnetic, but in a less degree than steel. Its specific gravity is 7.7. It is slightly tarnished by exposure to air, but requires an intense heat to burn it.

§ 2. It may be combined with oxygen in two proportions,

The *Protoxide* is obtained by precipitating the nitrate with potassa, and drying the precipitate in a retort. The oxide, while moist, is blue, as it dries the colour gradually becomes deeper, and at length appears black from the intensity of its blue colour. If left in water it becomes a red hydrate.

This is the oxide which exists in all the soluble saline compounds of cobalt.

If exposed to heat and air, it combines with an additional proportion of oxygen, becoming of a brown colour, and at length black. This is the *peroxide*.

Exposed to a strong heat confined from air it loses a part of its oxygen.

Chemists do not agree as to the weight of the smallest combining proportion of the metal, nor in relation to the

proportion of oxygen contained in its protoxide or deutoxide.

The protoxide contains according to

	Metal.	Oxygen.
Mr. Proust	100	19.8
Mr. Rolholf		27.3
Dr. Thompson		28.5
Mr. Brande		24.7

The deutoxide contains according to

Mr. Proust	33.25
Mr. Rolholf	40.85

§ 3. When cobalt in powder is poured into chlorine it inflames, burns, and produces a chloride. This chloride may be produced by exposing dry muriate of cobalt to a dull red heat.

Muriate of Cobalt may be obtained by a solution of the oxide in muriatic acid. If the peroxide be used, it is converted into a protoxide, the extra portion of oxygen attracting so much hydrogen from a part of the muriatic acid as is required to form water, and setting free the chlorine which was combined with it.

This muriate is a soluble deliquescent salt, of a blue green colour. When diluted it becomes of a pale pink colour. It is used as a sympathetic ink. Letters written with it are nearly invisible, but when the paper is gently heated they become of a brilliant green colour, which vanishes again as the paper cools.

§ 4. *Nitrate of Cobalt* forms into small red prismatic crystals, which are deliquescent and decomposed by heat.

When nitrate of cobalt is poured into liquid potassa a blue precipitate is formed, and if the vessel be immediately closed, it passes to violet and then to red, becoming a hydrated protoxide.

§ 5. Ammonia dissolves fresh precipitated oxide of

cobalt; a pale pink solution is produced which, on exposure to air, absorbs more oxygen and becomes deeper. It crystallizes in fine prismatic crystals of a bright pink colour.

According to M. Gmelin, a portion of acid is combined in the precipitate, by the agency of which the solution is effected, while pure oxide of cobalt is not soluble in ammonia.

A Carbonate of Cobalt may be obtained by decomposing the nitrate, muriate, or sulphate, by an alkaline carbonate. It forms a reddish blue powder.

§ 6. *Sulphuret of Cobalt* is produced by heating the oxide with sulphur. It is a yellowish white compound.

Sulphate of Cobalt is obtained by dissolving the protoxide in warm sulphuric acid, diluted with as much water. It forms red crystals soluble in twenty-four parts of water at 60°; they consist of protoxide of cobalt 1 atom 38, + sulphuric acid 1 atom 40, + water 7 atoms 63; = 141.

These crystals when dried at 500° fall into a blue powder, having parted with their water. This powder is again soluble in water.

At a bright red heat the acid escapes leaving a black oxide.

Sulphate of cobalt forms double salts with ammonia and potassa.

The saline solutions of cobalt are, generally speaking, of a pink colour when cold, and green when warm.

§ 7. Oxalic acid produces a rose-coloured precipitate in a solution of cobalt; ferrocyanate of potassa, a grass green; hydrosulphuret of ammonia, a black; solution of borax, a pink.

Phosphate of cobalt may be produced, by decomposing muriate of cobalt with phosphate of soda.

It is of a lilac colour and insoluble. When mixed with

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eight parts of fresh precipitated alumina, in the gelatinous state, and dried, it produces a blue pigment, which may be substituted for ultramarine.

Fluate of cobalt is of a rose red colour.

§ 8. Cobalt is capable of producing alloys with most of the metals. Bismuth and zinc are excepted. Its alloys appear to be unimportant.

It is extensively used as a colouring matter.

The ore of cobalt when roasted, is mixed with from two to three parts of powdered flint and fused; the compound thus produced, is known in commerce by the name of zaffre, and is much used for giving a blue colour to porcelain, earthenware, glass, or enamel.

Zaffre melted with a certain portion of glass, and powdered, forms the blue substance called smalts. It is said to be the colouring matter of the laundresses powder blue.

Article 11. Cerium.

§ 1. In a mineral found in Sweden, which contains silica, alumina, lime, and the oxides of iron and copper, was discovered about twenty years ago by M. M. Berzelius and Hisinger, an unknown body which, from its properties, they considered to be a metallic oxide. It has since been met with by Dr. Thompson in a mineral from Greenland.

To obtain the pure oxide; the mineral, which the discoverers named cerite, is calcined, powdered, dissolved in nitro-muriatic acid, the filtered solution neutralized by potassa, and the oxide of cerium precipitated by oxalic acid, or tartrate of potassa, washed and dried.

This metal retains the oxygen with such force, that it has not been reduced to the metallic state in the strongest furnace. Mr. Vauquelin obtained some minute globules only. By Mr. Children's large battery, the oxide was fused; and while intensely heated, burnt with a bright white flame.

and partly evaporated. The fused body being exposed to the air, fell into a light brown powder, which contained numerous particles of a silvery lustre.

The metal is said to be harder, more brittle, and whiter than cast-iron; and to break with a scaly fracture.

§ 2. *Two Oxides of Cerium* are described.

The protoxide is said to consist of cerium 100, oxygen 17.4, and is of a white colour.

By exposure to heat, it absorbs more oxygen, and becomes red.

The peroxide is reddish brown, and consists of cerium 100, + oxygen 26.1. They do not melt, nor form a cohesive mass.

The sulphate of the protoxide, produces white crystals.

The nitrate of the protoxide produces a deliquescent mass. Both these salts have a sweet taste.

The sulphate of the peroxide produces yellow crystals, which are soluble with difficulty.

The muriate produces deliquescent yellow crystals.

Carbonate of potassa precipitates a carbonate of cerium from these solutions. It is of a light texture, white, and on drying, has a silvery surface.

Article 12. Uranium.

§ 1. Uranium is rarely met with. It was discovered by Mr. Klaproth in 1789, combined with sulphur, in a mineral called pecheblende. It is found also, in the state of a hydrated oxide.

The pure metal is obtained by roasting the sulphuret, to separate the sulphur, and convert the metal into an oxide. The oxide is to be dissolved in nitro-muriatic acid, and precipitated by ammonia, an excess of which will dissolve any oxide of copper that may be present. The yellow oxide thus obtained, when washed and dried, is to be mixed with

a little oil or charcoal, and exposed to the heat of a blast furnace.

It is difficult to obtain this metal perfectly fused.

It is of a dark grey colour, with a fine grain and metallic lustre. Its specific gravity, when completely fused, is 9.

§ 2. It is little affected by air until strongly heated in it. At a red heat it glows strongly, and becomes a *protoxide* of a greyish black colour.

The nitrate precipitated by potassa, produces a hydrated yellow *deutoxide*, supposed to contain about 10 of metal to 1 of oxygen.

This oxide dissolves readily in muriatic acid, and yields deliquescent prismatic crystals of an olive green colour, consisting of oxide of uranium 100, muriatic acid 34.

§ 3. It dissolves also in nitric acid, producing prismatic crystals which are very soluble, and of a yellow colour. They contain oxide 61, acid 21, water 14. Heat expels a part of the acid, and leaves an insoluble subnitrate of a yellow colour.

When pernitrate of uranium is mixed with nitrate of lead, and precipitated by ammonia; the oxide falls down in combination, forming what has been called uraniate of lead. When this compound is heated in contact with hydrogen, water is formed, and the metals are reduced.

§ 4. This oxide of uranium dissolves in sulphuric acid, producing a neutral solution of a green colour, with an astringent aluminous taste, which on evaporation, deposits successive crusts of a green salt which is difficultly soluble. It appears to be a subsulphate: the remaining liquor has become acid, and does not crystallize.

The neutral salt appeared to consist of oxide of uranium 62, sulphuric acid 29.

§ 5. When carbonic acid is passed through a mixture of oxide of uranium and water, a considerable portion of oxide is dissolved; but when the solution is heated, the oxide is

again deposited, retaining little or none of the carbonic acid.

It is insoluble in pure alkalies, but is soluble in their carbonates.

The results of the experiments hitherto made to ascertain its equivalent, are very contradictory. Neither is it certain that only two oxides are capable of forming.

Section VII. *Of Metals producing Oxides reducible by Caloric alone.*

Article 1. Nickel.

§ 1. Nickel occurs native in Saxony. It occurs also in Britain, combined with iron. But it is mostly found combined with arsenic and oxygen; sometimes with sulphur, cobalt, and iron.

To obtain the pure metal, the ore sold in commerce by the name of speiss, is powdered and digested in dilute sulphuric acid, with the occasional addition of a little nitric.

The deep green liquid should be decanted from the undissolved arsenious acid, evaporated sufficiently, and set to crystallize. The sulphate of nickel forms into fine green crystals. The mother liquor contains a sulphate, and an arseniate of nickel, which may be separated by passing through it sulphuretted hydrogen, filtering, evaporating, redissolving, and crystallizing. If the quantity be large, it is necessary to repeat these operations several times. Lastly, the crystals should be redissolved, and recrystallized. These crystals dissolved in water, should be precipitated by an alkaline carbonate. To separate the cobalt, treat this precipitate with chlorate of lime, the cobalt will thus be peroxidized, and rendered insoluble in ammonia: then, by digesting the precipitate in ammonia, the nickel alone will be dissolved. From this solution precipitate the

nickel in the state of oxide or carbonate; this, when dry, is to be made into balls with oil and black flux, or charcoal; and embedded in a crucible filled with charcoal well closed, and then submitted, for two hours or more, to the strongest heat that can be raised.

Pure nickel is white, much like tin or silver. It receives a fine polish, superior to platinum. Its colour is changed by ignition, and slowly darkened. It is difficult to fuse. Its specific gravity is 8.4, and when hammered, 8.7. It is somewhat malleable, and may, while heated, be forged into bars, or hammered into plates. It may be drawn into fine wire. It is difficult to solder, on account of the surface oxidating when heated. It is acted on by the magnet, and is capable of becoming magnetic.

§ 2. When ignited in the air, it absorbs oxygen, and is converted into a dark brown oxide, which is still magnetic. When ignited and introduced into oxygen gas, it burns and scintillates.

When 100 parts of nickel are dissolved in nitric acid, and precipitated by potassa, a pale green hydrate falls down; which, on exposure to a red heat, leaves a *greyish protoxide*.

This oxide readily dissolves in ammonia, producing a blue solution. By means of ammonia, it is easily separated from oxide of iron.

A black *peroxide* is said by M. Thenard, to be formed by passing chlorine through water, in which the hydrate is suspended.

When acted upon by acids, it parts with the second portion of its oxygen, and combines with them in the state of a protoxide.

According to the experiments of M. Lassaigne, the protoxide contains nickel 1 atom 40, oxygen 1 atom 8. The peroxide 1 atom 40, oxygen 2 atoms 16.

In a very high temperature these oxides part with their oxygen, and the nickel is reduced to the metallic state.

§ 3. When muriate of nickel is evaporated to dryness, and heated, brilliant yellow scales are produced. This is probably the *protochloride*, and contains nickel 1 atom 40, + chlorine 1 atom 36; = 76.

A *perchloride* is formed when the metal is heated in chlorine. It is an olive-coloured compound, consisting of nickel 1 atom 40, + chlorine 2 atoms 72; = 112.

Muriate of nickel is obtained by dissolving the oxide, or carbonate, in muriatic acid; or by solution of the metal in muriatic acid, with the necessary proportion of nitric acid.

Evaporation reduces it to a green crystalline mass, of a sweetish taste, which is soluble in about twice its weight of water.

Hydriodate of potassa produces an insoluble yellowish green precipitate in solutions containing nickel.

§ 4. Nitric acid acts readily upon nickel, and produces a green deliquescent salt, crystallizable in rhomboids, which appear to consist of oxide of nickel 1 atom 48, acid 1 atom 54, water 3 atoms 27.

The addition of ammonia, in excess, to this salt, produces a nitrate of nickel and ammonia, which may be obtained in green crystals, that are not precipitated by potassa or soda.

§ 5. Nickel combines with sulphur, producing a *proto*, and a *persulphuret*. Sulphuretted hydrogen does not precipitate the salts of nickel, but the alkaline hydrosulphurets do; producing black precipitates.

Sulphuric acid dissolves the oxide of nickel, or it may be made to act on the metal by the addition of a portion of nitric acid, from the decomposition of which oxygen is supplied. It crystallizes in four-sided green prisms, which are efflorescent, and soluble in nearly three parts of cold water. Its crystals consist of oxide of nickel 1 atom 48, sulphuric acid 1 atom 40, + water 7 atoms 63; = 151.

With ammonia, or with potassa, it forms a double salt.

The sulphate of nickel and iron forms a double salt also, which produces green tabular crystals.

§ 6. *Phosphate of Nickel* is precipitated upon adding phosphate of soda to a salt of nickel. It is a pale green, nearly insoluble powder.

Carbonate of nickel falls down as a green powder, when carbonate of soda is added to sulphate of nickel.

Ferrocyanate of potassa produces a peculiar pale grey precipitate, in diluted solutions of nickel. In concentrated solutions, the precipitate is pale green.

Arseniate of potassa added to a solution of nickel produces an arseniate of nickel of a pale green colour.

§ 7. The alloys of nickel, with other metals, are very little known. With copper, it forms a white hard malleable alloy, a valuable variety of white copper. It unites with iron; when added in small quantities, it renders it white, and lessens its tendency to rust; and in a degree lessens its malleability.

It is found in the proportion of from 1½ to 17 parts in the 100, combined with iron, both being more or less in the metallic state, in certain meteoric stones, a considerable number of which have, from time to time, fallen upon the surface of the earth. (See M. Howard: Philosophical Transactions for 1802.) These stones are found to have a strong resemblance to each other. They are generally composed of small metallic grains, cemented together by a softer matter. The metallic grains are chiefly iron, or iron with a little sulphur. The intermediate matter is generally made up of an uncertain proportion of silica, magnesia, iron, chrome, nickel; sometimes cobalt, alumina, lime, and manganese, have also been found.

Article 2. Mercury.

§ 1. Mercury is met with in Hungary, Bohemia, Germany, India, and Peru.

Sometimes it is found native, sometimes amalgamated with silver, but more frequently combined with sulphur in the state of cinnabar, or of grey sulphuret. In the former case, the metal may be obtained by mere distillation. In the latter, by distilling it with iron and lime, which combine with the sulphur, and retain it.

It is a well-known blueish white metal, which is fluid at the common atmospheric temperatures. Its specific gravity is 13.6. It becomes solid at —40°, or 72° below the freezing temperature of water. It is then malleable, and its specific gravity is increased to 15.6. At about 660° it is volatile, and may be distilled, and thus purified, if distilled slowly.

It is, like many other bodies, convertible into vapour in vacuo, at low temperatures. When the common barometer is exposed occasionally to the sun's rays, small globules of mercury will be seen collected at the summit of the glass cylinder, in the vacuum above the mercury, produced by its vaporization and condensation.

The vapour of the mercury at about 660°, is strong enough to support the pressure of the atmosphere. When exposed to a higher temperature, its force, like the force of other vapours, is proportionally increased.

Pure mercury preserves the brilliancy of its surface, under ordinary circumstances, and is not oxidized by the action of air, until the temperature is raised to 600°.

§ 2. It may be combined with oxygen, nevertheless, in two proportions. The combination is retained by a slight force, and the double proportion of oxygen is attracted with stronger force than the single.

The *protoxide* is black, and may be obtained by agitating the metal for a length of time in oxygen gas; or more readily, by decomposing pure calomel by lime water, or solution of potassa.

If kept at the temperature of about 600° for a length of time, it absorbs a further portion of oxygen. If heated to

about 670°, it is decomposed, and pure mercury distilled over.

The *Peroxide of Mercury* is produced by exposing mercury, or its protoxide, to a temperature of 600° nearly, in a flat vessel, with a long narrow neck, until it assume the appearance of dark-red scaly crystals. This process generally occupies many days.

This oxide, when thus produced, is the calcined mercury of physicians, or the red oxide of mercury.

The protoxide is supposed to consist of mercury 1 atom 200, + oxygen 1 atom 8; = 208.

The peroxide of mercury 1 atom 200, + oxygen 2 atoms 16; = 216.

Peroxide of mercury has a red colour, and an acrid metallic taste.

It is partially decomposed by long exposure to light. When gently heated it becomes black, but returns to its colour on cooling. Before it is heated to redness, the oxygen escapes, and the pure metal begins to evaporate.

The protoxide of mercury, and its saline compounds, are all mild safe medicines. The peroxide and its saline compounds are generally acrid and violent in their actions on the stomach: some of them are violent poisons.

§ 3. When mercury is introduced into chlorine gas it burns, and a chloride is produced.

Mercury combines with chlorine in two proportions, producing two compounds, which differ essentially from each other in their properties. They are both much used in medicine.

The *protochloride*, under the well known name calomel, is a safe medicine when used with judgment. The perchloride is a virulent poison.

The protochloride of mercury, called also calomel, sweet mercury, and in the London Pharmacopœia, hydrargyrum submurias, requires a circuitous process for its preparation.

It may be obtained in several ways. The most simple is, to dissolve as much mercury in diluted nitric acid, as it can act upon, applying heat towards the end of the solution; pour this, while hot, into a solution of muriate of soda, made with as much of the salt as equals half the weight of the mercury, and acidulated with muriatic acid; a yellowish white precipitate falls down, which, when well washed, is a protochloride of mercury.

In the London Pharmacopœia it is ordered to be prepared by a different process.

The protochloride sublimes into a crystalline cake, and when the sublimation is slowly conducted, produces transparent colourless prismatic crystals. Its specific gravity is 7.2.

Formerly this preparation was ordered to be sublimed from seven to twelve times, with the view of increasing its purity. It had, however, a contrary effect; for every sublimation decomposed a portion of the calomel, and produced a portion of corrosive sublimate.

It is composed of mercury 1 atom 200, + chlorine 1 atom 36; = 236.

The crystalline cake affords a yellowish streak when scratched, and the powder has a yellowish tint. It is tasteless and insoluble. By long exposure to light, it is darkened on its surface, and partially decomposed.

It has occasionally been found native.

When a small proportion of calomel is thoroughly mixed with a little water, by rubbing in a mortar, and then a large proportion of solution of potassa is poured at once upon it, a perfectly black precipitate is obtained. This, when gently dried, and rubbed, yields about one-quarter of pure mercury, and a portion of bichloride is produced.

When lime water is added in a similar manner, a partial decomposition is produced, and is usually imputed to the previous impurity of the calomel.

It appears from the observation of Mr. Hemel, as related by Mr. Brand, (Journ. Science, 36.) that muriate of soda and of ammonia boiled upon calomel, effect a partial decomposition, and produce a portion of bichloride.

These changes, and others that are similar, *appear* to be consequent to a weaker attraction existing between the metal and oxygen, chlorine, or sulphur, in the respective proto, than in deuto-combinations. The latter have a strong disposition, also, to combine in double salts, which will tend to favour their production on the introduction of a third agent.

Bichloride of Mercury may be produced, by burning mercury in chlorine gas. It is usually prepared by decomposing persulphate of mercury with chloride of sodium, or dry common salt.

The two bodies are well mixed together, and exposed to heat in a proper subliming vessel. A double decomposition is produced; the chlorine and mercury are sublimed in the state of a perchloride, while the sulphuric acid and sodium, with the oxygen from the mercury, produce a sulphate of soda which, not being volatile, is left at the bottom of the retort.

It consists of mercury 1 atom 200, + chlorine 2 atoms 72; = 272.

It is produced in white crystalline cakes. Its specific gravity is 5.2. It has an acrid nauseous metallic taste. It is soluble in twenty parts of water at 60°, and is converted into a permuriate, it dissolves in half its weight of boiling water, in two parts of alkohol, and in about three of ether. The watery solution is slowly decomposed by the action of light; while the muriate of mercury and ammonia is very soluble in water, and the solution is permanent. Hence muriate of ammonia is frequently added, to increase the solubility of corrosive sublimate.

It readily sublimes when heated, producing a very acrid vapour, which whitens copper-plates.

It is soluble, without decomposition, in sulphuric, nitric, and muriatic acids. With potassa, soda, and lime, it gives an orange or a red precipitate: and is decomposed by several of the metals. It produces double salts, with muriates of the alkalies, of baryta, and magnesia; all of which are much more soluble than the simple permuriate.

Ammonia, when added to a solution of perchloride of mercury, produces a white precipitate, which is a subpermuriate of ammonia and mercury.

Chloric acid dissolves both oxides of mercury. The protochlorate is a yellowish compound. The perchlorate crystallizes, and has an acrid taste.

Iodine combines with mercury, producing a yellow protiodide and a red periodide.

§ 4. Nitrate of protoxide of mercury, or protonitrate, is obtained by dissolving mercury in nitric acid, diluted with three parts of water; the mercury should be added in successive portions until the acid is saturated, the mixture being kept cold. The solution should be evaporated under an exhausted receiver, when it produces crystals which are soluble in water.

A *Pernitrate* is produced by dissolving mercury in strong nitric acid. It becomes peroxidated, and produces prismatic crystals. When the solution is heated, a yellow precipitate appears, which seems to be a subpernitrate.

From the phenomena which appear during the solution of mercury in nitrous acid, under various circumstances, it is probable that there are other nitrates besides those above named; but the subject requires further elucidation.

When the nitrates of mercury are exposed to a heat, gradually raised to an obscure red, the nitric acid escapes, and the peroxide is left in brilliant shining red scales, still retaining a minute portion of acid, about 0.15 per cent.

§ 5. *Cyanuret of Mercury* may be produced by boiling one part of red oxide of mercury with two of Prussian blue in eight parts of water, and filtering the solution while hot. As it cools, quadrangular prismatic crystals are formed, which have a metallic taste. When purified by solution, and re-crystallizing, they are of a dull white colour, and consist of mercury 1 atom 200, + cyanogen 2 atoms 52; = 252.

When boiled upon red oxide of mercury, it combines with a portion of it, without any decomposition or evolution of oxygen. The compound thus produced, crystallizes in scaly crystals. On the application of heat it is decomposed, cyanogen is given out, nitrogen, and carbonic acid; if water be present, ammonia, and hydrocyanic acid also; and charcoal is left in the retort, while the mercury assumes the metallic state.

§ 6. When sulphuretted hydrogen is passed through a dilute solution of nitrate of mercury, a black precipitate is produced, which appears to consist of, according to Giboucourt, mercury 1 atom 200, + sulphur 1 atom 16; = 216. It is a proto-sulphuret therefore.

When equal parts of mercury and sulphur are rubbed for a time, the result is a black compound, called *Ethiop's mineral.* It may be produced also by pouring the mercury into the sulphur while melted. During the combination, which is rapid, a considerable heat is generated, sometimes amounting to ignition.

When Ethiop's mineral is boiled in repeated portions of a solution of potassa, a part of the sulphur is dissolved, and at length a black powder remains, that is not acted upon by potassa, nitric, nor muriatic acid.

When dried, it is of a dark violet hue, and wholly sublimes into a perfect cinnabar or bisulphuret. (See Mr. Brande, Journ. of Science, 36.)

When one part of sulphur is mixed by melting it with five of mercury, a dark grey sulphuret is produced, which, on applying heat in a close matrass, sublimes into a dark red crystalline mass. This is a *Bisulphuret of Mercury*, in commerce called cinnabar, and when powdered and levigated, produces that beautiful scarlet pigment, named vermillion. It consists of mercury 1 atom 200, + sulphur 2 atoms 32; = 232.

It is decomposed by heat in the open air, and slowly evaporates. It is decomposed when heated with alkalies and alkaline earths.

Sulphuret of mercury, or cinnabar as it is called in commerce, exists native, and is the principal source of the mercury of commerce. It occurs massive, crystallized, and of various colours, from dull grey to bright red.

Protosulphate of Mercury is produced, by boiling mercury with its weight of sulphuric acid. A part of the acid is decomposed, sulphurous acid is evolved, the metal is converted into a protoxide, and combines with the remaining acid.

It is a white salt, requiring 500 parts of water for solution. It crystallizes upon evaporation in prisms. It consists, according to Fourcroy, of sulphuric acid 12, protoxide of mercury 83, water 5. If this analysis be correct, it contains 3 atoms of acid to 4 of mercury.

It is precipitated black by alkalies.

Persulphate of Mercury is obtained by boiling one part of mercury in three of sulphuric acid. A white mass is obtained, more soluble than the protosulphate, which forms prismatic crystals. It is said to consist of acid 2 atoms 80, peroxide 1 atom 216, exclusive of water.

Subpersulphate of Mercury is produced when boiling water is poured upon the persulphate: it is precipitated as an insoluble yellow powder, known by the name of

turpeth mineral. It appears to consist of 1 atom of the peroxide and 1 of acid.

A bipersulphate is left in solution.

The persulphates are precipitated red by potassa and soda. With ammonia the persulphate produces a white double salt.

§ 7. The compounds of phosphorus and mercury are unimportant.

The alkaline carbonates produce buff precipitates in solutions of either oxide, which appear to be carbonates of the proto and peroxides.

A borate of mercury is produced by decomposing nitrate of mercury by borax. It is an insoluble yellow powder.

The arseniates of mercury are of a pale yellow colour.

Chromate of mercury is produced by precipitating nitrate of mercury by chromate of potassa. It is of an orange-red colour.

The saline compounds of mercury are volatile at a red heat. When distilled with charcoal, mercury is produced.

The compounds of the protoxide are precipitated black, those of the peroxide of a reddish colour, by potassa or lime-water.

The soluble salts are precipitated whitish by ferrocyanate of potassa; black by sulphuretted hydrogen: when a plate of copper is immersed into them, it decomposes them by its stronger attraction for oxygen, and the acid, and precipitates the mercury in the metallic state.

§ 8. The combinations of mercury with the different metals are called amalgams. In its amalgamation with potassium and sodium brittle compounds are produced, and heat is evolved.

Amalgams of silver, and of gold, are used in some kinds of gilding and silvering. An amalgam of zinc and mercury is used to increase the exciting power of electrical machines.

When mercury is negatively electrified in a little concentrated ammonia, or rather muriate of ammonia, the metal undergoes the curious change of being very much increased in bulk, and becomes slightly consistent. This phenomenon has been named the metallization of ammonia. This substance appears to contain ammonia and mercury, and nothing else. But it is still worthy of further examination.

Article 3. Platinum.

§ 1. Platinum is found in small steel-coloured metallic grains, which are hard and malleable, chiefly at Guadalcanal in Spain, in Choco, New Grenada, and Barbacoas, and some other parts in South America, where it is associated with gold. It is met with in an ore from the Brasils also; and in small quantity in some other places, generally in the vicinity of silver ores.

This metallic ore generally contains minute proportions of gold, and of the four metals, palladium, iridium, osmium, and rhodium, which seem ever attendant upon platinum: it generally also contains copper, lead, and iron, but the principal part of the mass is metallic platinum.

Pure platinum is obtained by solution of the ore in nitromuriatic acid, and pouring the solution into a solution of muriate of ammonia, as long as any precipitate falls down. This process is repeated, and the precipitate when dried, is exposed to the strongest heat of a blast furnace, and while hot, pressed and hammered into a solid mass.

It is a white metal, approaching more to iron than to silver in colour. It is extremely difficult of fusion, but fuses readily by the oxydrogen blow-pipe. Its specific gravity is from 21.5 to 22.6, being much increased by hammering. It is hard, very ductile, tenacious, and

tolerably malleable. It may be drawn into wire one three-thousandth of an inch in diameter, and it may be rolled into thin foil. It is unaffected by the joint action of air, and the heat of the strongest furnaces.

It is not acted upon by any simple acid.

It is soluble in nitromuriatic acid. A very corrosive solution is produced, which tinges animal substances of a dark colour.

Of all the metals it is the worst conductor of heat and of electricity. It is elastic in a degree sufficient for the pendulum springs of watches.

Like iron, it has the property of welding at a white heat, either with another piece of platinum, or with iron and steel.

§ 2. It appears probable that oxygen is capable of combining with platinum in three definite proportions. But the attraction between them is very slight, and the investigation of the products obscure in consequence.

By precipitating nitromuriate of platinum by potassa in excess, Messrs. Vauquelin and Berzelius obtained a protoxide, consisting apparently of platinum 1 atom 98, + oxygen 1 atom 8; = 106.

A deutoxide was obtained by Mr. E. Davy: he boiled fulminate of platinum in strong nitric acid, exposing the product to a heat a little below redness, washing the product with dilute potassa and drying. It was of a dark iron-grey colour. It was not acted on by water, nor by nitric, sulphuric, nor phosphoric acid; nor by muriatic or nitromuriatic till heated. By analysis, it yielded 100 metal and 11.9 of oxygen. If it be a definite compound its composition may be stated at platinum 1 atom 98, + oxygen 1½ atom 12; = 110.

A peroxide, which is a yellowish brown powder, becoming darker on drying, is obtained by decomposing the nitromuriate of platinum with hot sulphuric acid, and

precipitating with soda. It consists of platinum 1 atom 98, + oxygen 2 atoms 16; = 114.

§ 3. Protochloride of platinum is obtained by evaporating the nitromuriate to dryness, and heating it nearly red. On raising the heat to redness, it gives off the greater part of the chlorine.

Nitromuriatic acid readily dissolves platinum, the nitric acid is decomposed, and the compound is a muriate. The solution is capable of affording crystals which are deliquescent and acrid. The addition of muriate of ammonia produces an insoluble double salt, a muriate of platinum and ammonia, which is decomposed by a red heat; the muriate of ammonia and the chlorine being evaporated, and leaving the metallic platinum in the state of a light porous grey mass.

Potassa also, and soda, precipitate platinum in the state of a double salt

Ferrocyanate of potassa produces no precipitate, neither does sulphate of iron.

Muriate of platinum is decomposed by sulphuric ether, which retains the platinum in solution as it does gold. This solution is employed as a means of applying a thin coat of platinum to the surface of steel, to prevent its rusting.

Muriate of tin, even when much diluted, produces a peculiar red precipitate in a diluted solution of platinum, and is a good test of platinum. One drop of the recent solution gives a bright tint to a very diluted solution of the muriate of platinum.

§ 4. Sulphurets of platinum may be produced by heating sulphur with platinum in a state of minute division. A sulphuret is obtained also by passing sulphuretted hydrogen through a solution of muriate of platinum. A third is produced by heating together three parts of ammonio-muriate of platinum and two of sulphur.

A sulphate of platinum is readily produced by acting on the sulphuret with nitric acid: it is a very soluble brown salt; it produces triple salts with soda, potassa, and ammonia.

When a strong solution of this sulphate is mixed with an equal volume of alkohol, and gently heated, a black powder falls down, which, when well washed and dried at a gentle heat, is in small lumps easily reducible to an impalpable powder, tasteless, and insoluble. When gently heated, it detonates feebly, with a hissing noise and a flash of light; the platinum at the same being reduced. When poured into gaseous ammonia, it becomes red hot, and scintillates. Alkohol decomposes it. A small portion of it laid upon a piece of paper wet with alkohol, hisses and becomes red hot.

A fulminate of platinum may be prepared by precipitating the sulphate by ammonia, boiling the precipitate in solution of potassa, and drying it. It explodes at about 400°.

The other salts of platinum are obtainable by double attraction, the acids being previously combined with potassa.

§ 5. Platinum is acted on by pure potassa and its nitrate, which is decomposed. Some of the metals or their oxides combine with it, at a high temperature, and the compounds are readily decomposed by various agents; in consequence of which properties, the use of platinum crucibles is considerably limited.

When the muriate of platinum and ammonia is exposed to a low red heat until the fumes cease, it is reduced to the state of extremely light and porous platinum, in the metallic state. If a mixed stream of hydrogen and oxygen, or atmospheric air, be passed over it, it shortly becomes heated to whiteness. The same phenomenon takes place when the porous platinum, or small pellets of it made up with pipe-clay, are passed into a vessel containing a mixture of these gasses. It is extremely convenient, therefore, for

producing the combination of these gasses in eudiometry, which it does more completely than the electric spark even; and for procuring occasional light.

The cause of this property is not understood, but it appears to be existent in an inferior degree in some other metals.

The infusibility of platinum renders it very difficult to unite it into a mass preparatory to forging it, and forming it into vessels. Sometimes it is rendered fusible by metallic arsenic, and the arsenic evaporated during the forging. Sometimes it is amalgamated with mercury, and the mercury is partly forced out by strong pressure, and the remainder evaporated in the forging

It is capable of alloying with several metals. It has a strong attraction for lead, tin, zinc, and antimony. When a piece of platinum foil is rolled up with a piece of lead foil, and a flame be directed by a blow-pipe upon the edges of the roll, the metals combine with great force, emitting heat and light, and scattering their particles about.

Platinum is supposed to give additional toughness and hardness to steel, when from one to three per cent. is added to it; but it increases the solubility of steel in acids. Equal weights of steel and platinum produce a hard alloy, which takes a beautiful polish, and, it is said, does not tarnish. In small proportion it hardens gold, but whitens it very much.

Article 4. Rhodium.

§ 1. When platinum has been precipitated from the solution of the native ore in nitro-muriatic acid, by muriate of ammonia, the solution is still considerably coloured. It contains a portion of ammonio-muriate of platinum, and two other metals that are unknown elsewhere, generally a proportion of lead, iron, copper, and a minute portion of some other metals

If a plate of zinc or iron be immersed in the solution, it separates all the other metals in the state of a black powder. Nitric acid much diluted will, when gently warmed, dissolve the copper and lead. Let the precipitate be digested into nitro-muriatic acid, adding a solution of muriate of soda, and evaporating to dryness. The dry mass will contain soda-muriates of rhodium, palladium, and platinum. By repeated washing with alkohol, the two latter are separated. A red substance is left, which is soluble in water. From the solution in water, a plate of zinc precipitates a black powder in quantity about an hundredth part of the ore. When intensely heated with borax, it puts on a white colour, and a metallic lustre. It has scarcely been completely fused, except with sulphur, arsenic, or other metals.

Its specific gravity appears to be nearly 11. It is soluble in acids, producing compounds which have not been crystallized. It forms double salts with the alkalies.

It alloys with most of the metals; mercury is an exception.

When an alloy of rhodium with gold or silver is exposed to the agency of nitric or nitro-muriatic acid, the rhodium is not acted on. When alloyed with bismuth, copper, or lead, the compound is dissolved completely in nitro-muriatic acid.

The chloride of rhodium is of a rose-colour, and soluble in alkohol. It is not precipitated by ferroprussiate of potash, by hydrosulphuret of ammonia, nor by muriate of ammonia.

The alkaline carbonates do not affect it, but the pure alkalies precipitate a yellow oxide, which is soluble in all such acids as have been tried.

It alloys with steel. When added to steel in the proportion of from one to two per cent. it is said by MM. Faraday and Stoddart to communicate great hardness to it.

Article 5. Palladium.

Palladium may be obtained from the coloured solution left after precipitating the platinum from the nitro-muriatic solution by muriate of ammonia, on adding to the filtered liquid a solution of cyanuret of mercury. The precipitate which falls down is converted into metallic palladium, when fused in a crucible.

Palladium nearly resembles platinum in colour and brightness. It is harder than iron, malleable and ductile. Its fracture is fibrous and regular. Its specific gravity is 11 to 11.8 nearly. Its power of conducting heat, and its expansibility is nearly as platinum. When exposed to a red heat in an open vessel, it is slightly oxidated. On raising the fire to a great intensity, it is restored to its colour, and melted into a button.

It combines readily with sulphur, and produces a compound which is whiter than the metal.

It is acted on by potassa and soda, even in the metallic state. Ammonia is capable of dissolving a small quantity of it, acquiring a blueish tinge.

Muriatic acid, when heated or boiled upon palladium, acts on it, acquiring a fine red colour. Nitro-muriatic acid is the proper solvent of palladium; it acts with great energy, and produces a beautiful red colour.

Pure nitric acid dissolves the oxide, forming a fine red solution. No nitrous gas escapes during the action. Nitrous acid acts with more energy on palladium than nitric acid does.

Ferrocyanate of potassa produces an olive-coloured precipitate in solutions of palladium.

Prussiate of mercury affords a precipitate which detonates at about 500°.

When heated to a high temperature, if palladium be touched with sulphur, a fusible sulphuret is instantly produced, that is white and very brittle.

Sulphuretted hydrogen and hydrosulphurets precipitate palladium from its solutions of a dark brown colour.

Sulphuric acid, when boiled with palladium, acquires a beautiful blue colour, dissolving with difficulty a portion of the metal.

These alkalies generally precipitate their salts of an orange colour, but an excess partly redissolves them.

All the metals, gold, silver, and platinum excepted, precipitate solutions of palladium.

Fresh made muriate of tin produces a deep orange or brown precipitate, and is a delicate test of palladium. When too large a quantity is added, a green solution is produced.

Palladium alloys readily with other metals. In small proportion, it destroys the colour of gold, and hardens it at the same time.

Article 6. Osmium.

Osmium. When the small grains or ore of platinum are submitted to the action of nitro-muriatic acid, a black powder remains undissolved. When this black powder is fused with potassa, and water added, a yellow alkaline solution is produced, containing an oxide of osmium. The alkali should be saturated with sulphuric acid, and the mixture distilled in a retort. The oxide of osmium rises with the water, and passes into the receiver. The distilled solution has a sweetish taste, and a peculiar smell, which has been compared to new bread. When the water solution is shaken with mercury, an amalgam is produced, from which the mercury is separated by distillation, and the osmium left pure.

The metal is of a dark blue-grey colour. It bears the heat of the strongest furnace without being fused, or volatilized, unless combined with oxygen. It is insoluble in acids. When exposed to heat and air, it readily absorbs oxygen, and evaporates.

The oxide gives up its oxygen to all metals but gold and

platinum. It readily combines with alkalies, producing a yellowish solution, which, when concentrated, communicates a yellowish stain to the skin. The solution in water is colourless. With infusion of galls, it changes to a purple, and then to a blue colour; with alkalies and lime to a yellow.

It is capable of alloying with different metals; but, the small quantity in which it is found, does not allow it to be applied to any general use.

Article 7. Iridium.

After the osmium is separated by means of potassa from the black powder mentioned in the last article, another metal remains in it. If it be digested in heated muriatic acid, a dark blue solution is obtained, which changes first to an olive-green, and then to a deep red. By the alternate agency of this acid and potassa, the whole of the powder may at length be dissolved. When the muriate is evaporated to dryness, re-dissolved, filtered, and again evaporated, octædral crystals are obtained, which produce a deep red solution in water.

The metal may be obtained by precipitating this muriate with a plate of zinc, or by exposing it to a strong heat.

The product is of a white colour, but perfectly infusible in the strongest furnace. Mr. Children has fused it, however, with his powerful voltaic battery into a metallic globule, which was white, very brilliant, and although porous, had a specific gravity of 18.7.

It has been combined with sulphur, and alloyed with gold, tin, copper, lead, and hardened them. Lead separates from it by cupellation.

Article 8. Silver.

§ 1. Silver has been met with abundantly in Spain, in different parts of Britain, and of Europe generally, and very abundantly in America.

It frequently occurs native, in different sized masses, in the metallic state nearly pure, sometimes combined with gold. More frequently it is mineralized with sulphur, also with arsenic, antimony, bismuth, and lead, and sometimes two or more of these.

Pure silver is obtained by dissolving common standard silver in pure nitric acid diluted with an equal part of water. A clean plate of copper being immersed in the solution, will precipitate the silver in its metallic state. It should be washed, boiled in liquid ammonia, washed again, dried, and fused.

It may be obtained pure also by precipitating the nitric solution with muriatic acid, and then reducing the muriate by fusing it with twice its weight of potassa or soda.

Silver that is alloyed with copper, or any easily oxidable metal, is purified, very generally, by the silver refiners, by the process called cupellation. It has, as is well known, a pure white colour, and is susceptible of great brilliancy. It melts at a bright red heat, and is remarkably brilliant while in fusion.

Its specific gravity is 10.5. It is much harder than gold, extremely malleable and ductile, more so than any other metal except gold. Leaf silver is about one six-thousandth of an inch thick, and may be further extended. It may be drawn out into wire which is as small, or smaller, than a human hair. It is the best conductor of caloric that is known, and one of the best electrical conductors.

Silver resists the action of the oxygen of the atmospheric air, even at a very high temperature. The tarnish produced upon the surface of silver exposed to the air, is consequent

upon its strong attraction for sulphur, the vapour [illegible] is occasionally floating in the air or water which comes [illegible] contact with it.

Pure water has no action on it.

When exposed to an intense heat, from a three-foot le[illegible] it evaporates; and may be condensed in a metallic st[illegible] upon a plate of gold or copper. It crystallizes as it coo[illegible] from the liquid state.

§ 2. It is capable of forming an oxide with oxygen. [illegible] a powerful electric explosion be passed through fine [illegible] wi[illegible] it takes fire, and is converted into a black oxide. [illegible]n t[illegible] voltaic circle it may be burnt; it produces a beautiful gre[illegible] light, and is converted into an oxide, which evapora[illegible]tes [illegible] smoke.

Oxide of Silver may be obtained also by prec[illegible]ipitatin[illegible] nitrate of silver, with a solution of baryta, or lim[illegible]e. It is of an olive colour, and may be reduced to a metal[illegible]ic state, by heat alone expelling the oxygen.

From various experiments it is concluded to c[illegible]onsist of silver 1 atom 110, + oxygen 1 atom 8; = 118.

§ 3. [illegible]hen leaf-silver is heated in chlorine gas they combin[illegible]ith considerable force, forming a *chloride of silver*. [illegible]ompound, however, is usually produced by decom-[illegible]itrate of silver, with muriatic acid, or comm[illegible]on salt; it falls d[illegible]wn as a dense insoluble powder, consisting of silver 1 atom 110, + chlorine 1 atom 36; = 146.

It is of a white colour at first, but soon becom[illegible] brown on exposure to light. When dried, it does n[illegible] weight by exposure to a low red heat. It readily [illegible] and as it cools it hardens into a semitransparent crys[illegible] substance, formerly called horn-silver.

Exposed to a bright red heat, it slowly evapora[illegible] dense fumes.

When fused with twice its weight of potassa, or so[illegible] is decomposed, and metallic silver obtained.

It is more economically reduced by placing it in contact with iron, or zinc, covered with a dilute solution of muriatic, or sulphuric acid. An action shortly commences, and, after a time, the silver will be reduced.

The chloride is soluble in a solution of ammonia, the combination producing crystals, which are decomposed by exposure to the atmosphere from the escape of the ammonia: sometimes a portion of fulminate of silver is produced.

When moistened with water, it is decomposed by a current of hydrogen. It is decomposed by zinc also, or tin. If heated with either of these two metals in filings, an energetic action ensues, a chloride of zinc, or of tin, is produced, and the silver reduced; so much heat being extricated as to fuse the silver, or alloy. But it appears from Mr. Faraday's experiments at the Royal Institution, that pure hydrogen gas does not act upon chloride of silver, when both are defended from the light.

Native chloride of silver is occasionally met with in silver mines.

Chlorate of Silver may be formed by digesting oxide of silver in chloric acid. It crystallizes in rhomboidal crystals.

Muriatic acid does not act upon silver. When boiled in it; indeed, for a length of time, a slight crust appears.

Iodide of Silver is produced by the decomposition of nitrate of silver by hydriodic acid. It is of a greenish yellow colour. It is insoluble in water and in ammonia. It is decomposed when heated with potassa.

Iodate of silver is produced by the addition of iodic acid to the nitrate. It is a white powder, insoluble in water, but soluble in ammonia.

§ 4. *Nitrate of Silver* may be prepared by dissolving silver in nitric acid, diluted with three parts of water. When the ingredients are pure, the solution is transparent, and without colour. It crystallizes in caustic tabular crystals, which are soluble in their own weight of water, at 60°. It

consists of, silver 1 atom 118, + nitric acid 1 atom 54; = 172.

It undergoes a partial decomposition when exposed to light, and a part of the silver appears to be reduced.

When heated, the water of crystallization and a portion of the acid evaporates; and the nitrate fuses into a transparent fluid, which is usually cast into small cylinders, known in commerce by the name of lunar caustic. It is a brittle crystalline white body, which is decomposed at a red heat.

This nitrate is powerfully caustic. Animal and vegetable substances that are touched with a diluted solution of it, are not apparently coloured by it, if kept in the dark; but when they are exposed to the light, the colour soon changes to a dark brown, which cannot be removed.

By virtue of this property it has become the basis of all the indelible inks for marking linens, cottons, &c. and of compounds for colouring hair.

Nitrate of silver is decomposed by heat and by charcoal, sulphur, phosphorus, and hydrogen, which attract the oxygen, both of the acid, and of the base, upon being heated. Sulphur detonates with it upon being smartly struck with a hammer. Phosphorus explodes with it upon slight friction. When silk is dipped into a solution of nitrate of silver, and, while moist, exposed to a current of hydrogen gas, the silver is restored to its metallic brilliancy.

Fulminate of Silver is produced by precipitating nitrate of silver with lime-water. The washed precipitate is then digested in liquid ammonia. After about twelve hours the ammonia must be cautiously decanted, and the black powder should be dried upon soft paper, in divided portions. If struck, or rubbed with a hard body, even while moist, it explodes with great violence. When dried, it is not safe to handle in quantities larger than two or three grains.

The decanted ammonia still contains a quantity of this

fulminate in solution. On the application of a gentle heat it effervesces, and in cooling small crystals of the fulminate are produced, which are more suddenly and violently explosive than the powder that is precipitated.

The touching of them merely under the liquid often explodes them.

The composition of this fulminate, according to M. Liebig and Gay-Lussac, appears to be, cyanogen 1 atom, oxygen 1 atom, forming cyanous acid; to which add, silver 1 atom, forming a double compound which they name fulminic acid: the addition of another atom of silver, in the state of oxide, forms the fulminating powder.

It appears that the metallic basis, both of the fulminic acid, and of the fulminate, or of the latter alone, may be exchanged for another metal, for mercury or gold for instance, thus producing an argento, a mercurio, or an auro-fulminate of silver, mercury, or gold.

A stick of phosphorus, or a plate of copper precipitates the silver from its nitrate, with considerable metallic brilliancy.

The crystallization called the silver tree, or tree of Diana, is a precipitation from nitrate of silver by mercury. One part of nitrate of mercury, and two of nitrate of silver being mixed with sixteen of pure water; an amalgam of one part of silver, and seven of mercury should be added to it, and the flask, or vial containing the mixture, placed in a state of perfect rest. In the course of two or three days, the silver, amalgamated with a little mercury, will have separated in a brilliant metallic shrub-like form. The solution having become a nitrate of mercury.

Nitrate of silver is decomposed by the alkalies, the alkaline earths, and many of the oxides, as well as by the sulphuric, muriatic, phosphoric, and boracic acids.

Ammonia produces a double salt with it, that is soluble in an excess of ammonia.

Nitrate of silver is used also in medicine and surgery, and by chemists as a test for chlorine and its compounds.

Subnitrate of silver is said to be produced by adding a precipitate of metallic silver to a solution of the nitrate. A compound is produced which is very soluble, and crystallizes with difficulty. But it is still doubtful whether it contains a definite suboxide; or whether the additional quantity of silver may not borrow oxygen from the acid, and thus have converted the compound into a nitrite.

§ 5. *Carbonate of Silver* is precipitated by decomposing nitrate of silver with carbonate of potassa.

It consists of oxide of silver 1 atom 118, + carbonic acid 1 atom 22; = 140.

It is an insoluble white powder.

Carbonate of ammonia precipitates a double salt; a carbonate of silver and ammonia.

§ 6. Sulphur and silver strongly attract each other, and produce a dull dark grey *sulphuret*, which is brittle and fusible. It is a thin layer of this compound that forms the tarnish which appears upon silver plate when it has been dipped into egg, and some other animal substances; or when it has been long exposed to the atmosphere, particularly where coal gas is used.

It is met with native, sometimes nearly pure, as in the vitreous silver ore, sometimes combined with other metals, with lead for instance, or with antimony as in the ruby silver ore.

Hydrosulphuret of ammonia precipitates silver black.

Hyposulphite of Silver. Hyposulphurous acid produces those singular compounds first described by Mr. Herschel in examining the properties of this acid

When hyposulphite of soda is poured upon fresh precipitated oxide of silver, hyposulphite of silver and soda is formed. It is obtained also by pouring very slowly, a very

dilute solution of nitrate of silver, into an equally dilute solution of hyposulphite of soda.

When hyposulphurous acid newly separated from hyposulphite of baryta by sulphuric acid, is poured upon muriate of silver, it dissolves and decomposes it, and produces an hyposulphite of silver.

Double salts are produced with the other alkaline hyposulphites. When hyposulphite of ammonia is poured upon muriate of silver, solution follows, and a hyposulphite of silver and ammonia is produced. When alkohol is poured on the solution, it dissolves a part of the salt, and the remainder falls down as a white precipitate which must be dried in an air pump vacuum. It is extremely soluble. Its sweetness is pure and intense. One grain communicates a perceptible sweetness to two quarts of water.

All these compounds are remarkable for the pungent sweetness they produce when applied to the organ of taste The sensation is that of pure simple sweetness, but so intense as to be almost painful. Yet the bodies combined to produce them are severally remarkable for acrid, nauseous, bitter, and metallic tastes.

Chloride of silver decomposes many of the alkaline and soluble hyposulphites producing these compounds. If into the solution liquid potassa be dropped, a precipitate is produced which dries into small grey pearly scales of difficult solubility in water. This is a hyposulphite of silver and potassa. It is also distinguished by an extremely sweet taste.

§ 7. *Sulphate of Silver* is produced by the decomposition of nitrate of silver with sulphate of soda. It consists of oxide of silver 1 atom 118, + sulphuric acid 1 atom 40; = 158.

It is soluble in ninety parts of water 60°. Its saturated boiling solution crystallizes on cooling in small prismatic crystals.

A mixture of one part of common nitre with ten of sulphuric acid is used by refiners to separate silver from old plated copper, iron, or lead. This acid dissolves silver at a temperature below 200°; and scarcely acts upon copper, iron, or lead, until diluted to a certain extent with water; then these metals combine with the acid, and precipitate the silver.

Phosphorus and its acids act upon silver. The compounds they produce are of no importance.

Hydrocyanic acid produces a white precipitate in saline solutions of oxide of silver which, when heated, gives out cyanogen.

The metallic acids act also on silver, but their compounds are of no value. Chromate of silver soon loses its brilliant crimson tint, and becomes brown.

The soluble salts of silver let fall a dense white precipitate on the addition of a few drops of muriatic acid, which blackens on exposure to light, and is soluble in ammonia. The insoluble salts are soluble in ammonia. They reproduce the metal when heated with charcoal.

§ 8. Silver is capable of forming alloys with several metals. One hundred and eleven parts of silver alloyed with nine of copper form the standard coin of this country. It is more hard and elastic than pure silver. Its colour is scarcely affected. Steel alloyed with a minute proportion of silver is said to improve it for the construction of cutting instruments. It is frequently alloyed or amalgamated with mercury, for silvering over some other metals: for silvering brass a mixture of chloride of silver, chalk, and pearlash is used.

The process of refining silver by cupellation depends upon the property of silver, in common with two other metals, of having no attraction for oxygen, at a strong red heat; while other metals are oxidable and vitrifiable at that temperature, or easily rendered so by the addition of bismuth or lead, which besides being themselves oxidable and

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vitrifiable, have the property of favouring the oxidation and vitrification of other metals that may be present, gold, platinum and silver excepted.

The operation consists in laminating the alloyed or impure silver, inclosing it in a certain quantity of sheet-lead, in a cupel or shallow porous crucible of finely powdered bone earth; placing it under a muffle in a cupelling furnace, and gradually raising the heat to a bright red. The air circulates within the muffle upon the surface of the alloy: the lead is soon oxidized and vitrified, and sinks into the cupel carrying the oxidable metals with it, and leaving a brilliant button of pure silver.

Article 9. Gold.

Gold is almost always found native in the metallic state; sometimes in small detached grains, some of which are regular crystals, and generally contain small proportions of silver or copper. Sometimes it is combined with silver in large proportions, and also with platinum, iron, or tellurium.

It is chiefly found now in America, Hungary, and Siberia. It has been found largely in Asia, and in Spain, and occasionally in small quantities in Ireland, and numerous other places.

It may be obtained pure by solution in nitromuriatic acid, evaporating the solution to dryness, and redissolving the dry mass in distilled water. The pure gold is then precipitated in the form of a black powder, by a solution of protosulphate of iron, and may be washed with diluted muriatic acid, and fused.

The peculiar colour and lustre of gold is well known.

It melts at a bright red heat, and assumes a brilliant green colour when in fusion. Its specific gravity is 19.3.

Gold is soft, and is remarkable for its unfading brilliancy,

as well as its extreme toughness, malleability, and ductility. Of leaf-gold fifty-seven inches square weigh one grain nearly; so that its thickness is nearly a two-hundred-and-eighty-two thousandth part of an inch, and it may be further extended.

The wire which is used by gold lace makers is composed of silver previously covered with a plate of gold, drawn out, and flattened. The surface of the silver is so perfectly covered, that no part of it can be seen with a microscope. By computation it appears that the thickness of the gold must be about 3.384000 part of an inch.

§ 1. Its attraction for oxygen is so slight, and its fixedness in heat so great, that it has been kept at a bright red heat in a glass-house furnace for months together; unchanged in appearance or in weight. But a powerful electric discharge from a common machine, or from a voltaic circle burns it, with a bright green flame; and a purple powder is left which appears to be a protoxide.

From its very slight attraction for oxygen this metal is not acted on by any single acid. It is, however, oxidated, and dissolved by nitromuriatic acid; and from the solution a peroxide is precipitated by potassa, or any alkaline base, but more completely by magnesia. It is a reddish yellow precipitate, and must be dried at a temperature below 100°, as it readily parts with its oxygen.

This oxide is soluble in nitric, sulphuric, or muriatic acids, from which the gold separates gradually on standing. Its nitric solution affords a yellow deliquescent compound, which is decomposed by water.

§ 2. When gold-leaf is immersed in chlorine gas it inflames and burns, producing a deep yellow compound, which the addition of water converts into a muriate. When gold leaf is suspended in water saturated with chlorine it is dissolved.

A compound of nitric and muriatic acids is the usual acid

solvent of gold. The mixture mostly employed is one part of nitric acid by weight, to two of muriatic.

The gold is dissolved with effervescence, the nitric acid being decomposed, and furnishing oxygen to the gold, thus rendering it soluble in muriatic acid.

This solution corrodes animal substances, and tinges them of a deep purple. By slow evaporation it produces beautiful prismatic crystals of a rich topaz colour. Exposed to heat it becomes a chloride, and as the heat is raised the chlorine escapes, and the pure gold is left.

The addition of chromic acid enables muriatic acid to act upon gold, by giving up to the gold a part of its oxygen.

Ammonia readily precipitates muriate of gold of an orange or yellow colour, producing a compound which has the property of detonating with considerable violence upon the application of a slight heat, or friction. It appears to be a true fulminate; it contains about four-fifths of gold.

A piece of paper moistened with muriate of gold, and exposed to the light, becomes of a purple colour; this appears to be the protoxide.

When protosulphate of iron is added to muriate of gold, the mixture appears brown and muddy by reflected light; but when viewed by transmitted light it is of a beautiful green colour, produced by the extreme division of the nascent metallic gold, which soon falls down in the state of a brown powder. Protomuriate of tin, or even a piece of tinfoil, added to a solution of muriate of gold, causes a precipitate of a purple colour. This precipitate appears to be a compound of peroxide of tin three parts, and oxide of gold one part. The latter metal is in its lowest state of oxidation, but is soluble in muriatic acid. It is soluble in ammonia, producing a deep purple solution.

This is the purple powder of Cassius. It is used in enamel painting: it gives a fine red colour to glass. But

the colour varies according to the proportion of the respective oxides. As the proportion of tin increases, the colour approaches to violet; as the proportion of gold increases, it approaches to a rose colour. A violet compound contained 6 parts of tin to 4 of gold. A fine purple compound consisted of 2 parts of tin to 8 of gold.

When three parts of sulphuric ether are mixed with one of concentrated solution of muriate of gold, the salt is decomposed, and left nearly colourless; and the gold is dissolved in the ether. This compound is used for gilding polished steel, and some other polished metals.

When a stick of charcoal is immersed in a diluted solution of muriate of gold, and the vessel exposed to the sun's rays, the gold will be precipitated upon the charcoal in the metallic state, and exhibit a pleasing appearance.

When a diluted solution of gold in ether is painted upon silk with a camel-hair pencil; a current of hydrogen, or phosphuretted hydrogen, passed through it, will restore the gold to its brilliant metallic state.

Several of the vegetable acids, or of their saline compounds, when added to a muriate of gold and exposed to the sun, decompose it; and restore the gold to its metallic state. Thus, on the addition of oxalic acid, or binoxalate of potassa, carbonic acid escapes, and the gold shews its metallic splendour.

Metallic gold, in a divided state, as produced by the decomposition of the muriate, is employed in enamel painting, and in various other kinds of gilding.

§ 4. When sulphuretted hydrogen is passed through a solution of gold, a black precipitate falls down, which is a sulphuret of gold, consisting of gold 100, + sulpur 24.4.

When gold is precipitated by an alkaline sulphuret, the quantity of sulphur attracted by the gold that is precipitated, is variable. Sulphuret of gold is soluble in hydro-

sulphuret of potassa. Liquid potassa decomposes it, dissolves the whole of the sulphur, and a part of the gold; while the remainder is precipitated in the metallic state.

A phosphuret of gold is produced, by heating gold-leaf with phosphorus in a vessel free from air; or by precipitating a solution of gold by phosphuretted hydrogen.

Its colour is grey with a metallic lustre. It contains about 11 per cent. of phosphorus.

Freshly precipitated oxide of gold is soluble in potassa or soda. The compounds are named by M. Pelletier, aurates of these alkalies.

§ 5. Gold is capable of alloying with a number of the metals, and its alloys have been thought of such importance by physicians, chemists, and legislators, that they have occupied a great deal of attention.

The toughness of gold is diminished by alloying it with the following metals, nearly in their order—One part of lead renders two thousand parts of gold brittle. Bismuth and antimony have nearly the same effect, arsenic, zinc, cobalt, manganese, nickel, tin, iron, platina, copper, silver.

A small proportion of gold, it is said, renders steel harder and less oxidable.

The alloy with a little iron, is harder than gold, and is malleable and ductile. The metals expand during their combination from 1000 to 1015. Platinum, unless in minute quantity, destroys the colour of gold. The most valuable of the alloys of gold, is the standard gold for coinage, and for the manufacture of plate. The British standard gold contains one-twelfth of silver and copper, or copper only. It is perfectly ductile and malleable. Its colour is not injured. It is rendered much harder and more durable. Consequently, it is better adapted for coin, and for various other uses than pure gold.

Mercury amalgamates readily with gold; this compound is used in water gilding.

Gold has a strong attraction for copper. Its purification or assaying is therefore a more difficult and complicated process than the assay of silver: for unless some precaution be taken, the gold defends a small quantity of copper from the action of any other agent, whether it be oxygen, or an acid, or the action of lead in cupellation.

An alloy of gold with a little copper is, therefore, previous to cupellation, mixed with a known quantity of silver; and after the copper is removed by cupellation with lead, the silver is again separated from the gold by solution in nitric acid; partation as it is called.

DIVISION V.

OF THE COMBINATIONS PRODUCED BY VITAL AGENCY.

Section I. General Remarks.

Having given a general account of the various chemical agencies and elements, and endeavoured to explain, generally, what has been discovered of the laws that regulate their actions upon each other; before concluding, we will take a short survey of two other extensive classes of bodies, which we observe around us in surprising numbers and diversities, and in constant action. A little observation shews to us that they are perpetually undergoing changes, and that these changes are, in a limited degree only, subject to chemical laws.

All animal and vegetable matter is constituted, and compounded of certain of the chemical elements already enumerated. Their peculiar combinations are the result of a most wonderful, and unknown agency. This agent is not an object of sense, nor a subject of chemical research. It is inherent in each individual, for a time only. During that time, it exerts a powerful influence over the chemical actions of the elements subjected to its agency; and directs them to the production of such compounds and structures, as are adapted, by the wisdom of the Creator, to the final purposes and ends of each individual.

This agent is understood by the term life, or vitality.

By the agency of animal and vegetable vitality, communicated to the seed or ovum, and thence to the future off-

spring, each plant or animal, is enabled to absorb or assimilate certain bodies, to resolve them into certain compound elements or principles; and to combine these principles so as to produce the substances, of which are composed the organs and structures of its various parts. These compound principles are numerous and various. Generally speaking, they are very different from those produced by the same elements, when influenced by their chemical actions only.

These proximate principles, so long as they constitute a part of a living vegetable or animal, are not properly subjects of chemistry, but are supported or altered by the power that produced them.

But when an animal or vegetable loses its life, when it is dead, or when it is separated from the living body, it becomes subject to the general laws of chemical attraction. Then these different proximate principles, according to their properties, and according to the influence of the agencies surrounding them, remain, for a time, perfect; or are directly decomposed.

In general, vegetables and animals, more especially the latter, are, during life, penetrated with warmth and moisture; circumstances that expose them to the full force of chemical actions, and from which they are preserved by the powers of life. But so soon as life ceases, these agents act with full force: the structure soon gives way, the atmosphere, and other chemical agents, lend their assistance; new combinations are produced, and dissolved, and the greater part of the animal or vegetable, after successive changes, at length evaporates into air. The more complicated and delicate the structure, the more rapid is its dissolution.

Most of the proximate principles are capable of being separated, preserved, and rendered objects of chemical examination.

By their chemical actions on each other, and by the action of chemical agents upon them, they are decomposed, and sometimes new compounds are produced, the properties of which vary according to the properties of the bodies decomposed, and as such have been considered, although somewhat incorrectly, as animal and vegetable products. Amongst these may be named ammonia, alkohol, vinegar, &c.

On the present occasion, it is most convenient to let them remain in the place in which chemists have already placed them.

The proximate principles of animals and vegetables vary from each other in their properties, in a regular chain of gradation, some links of which may be seen to belong to both classes.

The vegetable proximate principles are very generally compounded, chiefly of carbon, hydrogen, and oxygen, in various proportions; frequently a quantity of nitrogen is detected in them, as well as other bodies, in minute proportions, some of which may, perhaps, be considered as accidental.

The animal proximate principles are composed chiefly of carbon, hydrogen, oxygen, and nitrogen, in a large proportion. Sulphur, phosphorus, and other bodies, are frequently in combination, in comparatively small proportions, and seem to form generally a part of the combination, but sometimes appear to be accidental.

Section II. *Of Vegetable Compounds.*

Part I. General Properties.

Of vegetables there are at present known nearly about 40,000 different species, and each of these species has respectively its various parts. Each of these parts is constituted of several proximate principles, and in numerous

cases some of these principles are peculiar to and characteristic of a particular species or genus of vegetables. The number of these proximate principles is consequently very great, so great, that a comparatively few only, more generally met with, have been subjected to chemical examination; and many of them can be brought together under general names, only by admitting remote approximations of resemblance. The various sugars, gums, starches, &c. are very generally met with, but they differ more or less from each other, as they occur in different vegetables.

Every phenomenon in nature, when considered alone, is curious and wonderful; and yet numberless phenomena are daily passing under our eyes, unnoticed and unthought of. One of the most surprising and incomprehensible is this: that all the numerous varieties of vegetable proximate principles are constituted, for the most part, of three, and in some few cases of four of the chemical material elements, modified occasionally with minute proportions of some one or more of a few other elements. Carbon, oxygen, and hydrogen are the general and chief constituents of all vegetable bodies; frequently a small, and sometimes a larger, proportion of nitrogen is present also.

Iodine, phosphorus, sulphur, silica, lime, magnesia, alumina, iron, and manganese, and some other bodies, are, one or other of them, often met with, but in quantities so minute as long to have escaped detection. Sometimes some of them appear to be in their pure state, sometimes combined with one or other of the following acids: carbonic, sulphuric, muriatic, oxalic, phosphoric, nitric, and sometimes with other acids which are of vegetable production. But in whatever state they are present, the proportion is generally very minute, and the chemist is quite unable in most cases to comprehend the part they perform. Thus a minute proportion of iodine has lately been discovered in certain fuci, or sea-weeds. Its uniform presence, and regular pro-

portion, lead to the probability that it is a necessary part of their composition, but how it acts is unknown. Phosphorus is very generally an ingredient in seeds, but its quantity is too minute to be detected in chemical analyses conducted in the common way, nor is its use at all understood. Potassa or soda are, one of them, present in all vegetables, varying from about seven parts in the hundred of the dry matter to one in the thousand. They are oftentimes detected in the liquids of vegetables, and were it not for the uniformity of their presence and proportion, often might be considered as accidental mixtures; but in what way they contribute to the formation of their structures, or to the constitution of their proximate principles, is wholly incomprehensible.

In some cases it is sufficiently apparent. Thus the silica found in straw, in the various grasses, in the bark of canes, and in the husks of many seeds, contributes to the formation of their hard polished surfaces. The superoxalate of lime in the leaves of sorrel; the hydrocyanic acid in various leaves and kernels; and the acids and sugars of various fruits; contribute to the production of their respective and peculiar flavours, and other properties.

The analysis of vegetables is usually considered as of two kinds.

The first is by the application of such agents as do not destroy, but merely separate, with as little chemical alteration as is possible, the different natural compounds, or principles, as they are called, of which the various parts and structures of the vegetable are made up.

The agents used in this kind of analysis are water, alkohol, ether, acetic acid, the mineral acids, and alkalies in a diluted state, and any other bodies that may be found convenient.

The second is called ultimate analysis. The intention of it is, to resolve any part of a vegetable, or of any of the vegetable principles, into the ultimate chemical elements, or

into combinations, of which the proportions are well known. Then, by the weight, measure, or estimation of the productions, their respective proportions in the body are inferred.

There is, however, a third kind of analysis, which is frequently employed, in the examination and comparison of vegetable principles. This is to ascertain the product of their decomposition by a particular chemical agent. Thus sugar, when decomposed by concentrated nitric acid, produces oxalic acid; lignin produces the same acid; but in smaller proportion, when heated in the same manner; but gum, when heated with nitric acid, produces an acid, which is named mucic or saccholactic acid, as well as a portion of oxalic and malic acids. Resins, on the contrary, produce artificial tannin. Guaiacum, a substance to all appearance a resin, is expelled from the list, because when treated with nitric acid, it produces oxalic acid, and not tannin.

The ultimate analysis of vegetable or animal matter, for the purpose of pointing out the exact proportion of their chemical elements, is of very recent introduction, and is as yet quite in its infancy.

It was introduced by M. M. Gay-Lussac and Thenard, who proposed an apparatus for the complete decomposition of a given quantity of any vegetable or animal principle, in conjunction with a known quantity of chlorate of potassa, or oxide of copper; and preserving the water, and resulting gasses, for examination; so that, from the proportion of them produced, and of the chlorate or oxide decomposed, the elements of the bodies examined might be inferred by calculation.

There is so much nicety necessary in accurately conducting this delicate experiment, that the difference between the results of different experimentalists is not much to be wondered at; but certain approximations are obtained, which further improvement in the mode of analysis may fairly be expected to improve upon.

At present, the minute portions that are the subject of experiment, obliges the chemist to overlook altogether the sulphur, phosphorus, potassa, silica, or any other body that may be present in small quantity; and which probably assists in the constitution of each atom of the decomposed principle.

Wherever man can form a judgment of the works of the Creator, it is observed that every efficient is produced in the shortest way, and without waste of matter, or of action. In combination, therefore, when one or other of these elements are uniformly present, although in minute quantity, their necessity, as a component part, may be fairly inferred.

The inferences drawn by chemists, from the improved and more definite ultimate analysis of the vegetable, and of the animal principles also, must be received with some doubt; for, when one or more of these bodies are present in a proximate principle, if they form, as there is reason to apprehend they do, a necessary constituent part of each atom, these atoms must, in many cases, consist, not of from one to twenty atoms of the carbon, and other principal ingredients, but of from one to twenty hundred, or an atom of the sulphur, phosphorus, potassa, or silica, cannot be admitted.

The proximate principles of vegetables possess great variety in their sensible properties. After they are done with by the vegetable producing them, they contribute generally to the support and nourishment of other vegetables; they contribute extensively to the support of animals, particularly of man. They also supply him with materials for building, and for cloathing, for colouring and dying, and numerous other arts and uses of comfort or convenience; they supply also numerous medicines, adapted, more or less, to almost every medicinal indication, and every curable disease; and, moreover, numerous class of deadly poisons. Yet all this variety of bodies, when subjected to a minute chemical

analysis, scarcely ever indicate any thing but the three elements just named,—carbon, hydrogen, and oxygen, in varied proportions, and sometimes a portion of nitrogen united with them. The proportion of the other elements that may be present is so small, as to escape detection; unless the analysis is conducted at the expense of a large quantity of the body to be examined.

These manifold metamorphoses, produced by a single agency, upon three or four bodies, is wholly beyond human reasoning; and shews how little, comparatively speaking, is known of the elementary constitution—the essentia—of what we call matter; the properties of which we suppose ourselves so well acquainted with.

The chemical constitution of one of the most deadly of vegetable poisons, has been clearly ascertained. Hydrocyanic acid, the cause of the poisonous nature of laurel, and of some other vegetables, is composed of 1 atom of nitrogen, 2 of carbon, and 1 of hydrogen, three elementary bodies that enter into numerous of our most nutritious articles of food. A piece of beef consists of the same elements, combined in different proportions, with a small proportion of oxygen.

This subject of poisons is a most important one. How much philosophers, physiologists, and physicians know on the subject beyond the mere symptoms they produce in their action upon a living animal, may be judged of from these facts.

Thousands of experiments have been made, and many thousands of animals have been destroyed, in cruel tortures, to ascertain a few facts that might have been known at a comparatively small expense of life and torture.

But a few years are past, since it was the fashion to attempt the explanation of the operation of poisons on the animal systems, upon what were called mechanical principles. It was supposed that bodies, the parts of which

were wholly, or as far as possible, disintegrated by pulverization, must pierce and destroy the stomach like swords, spears, or daggers. Physiologists then destroyed many thousands of animals before they would be convinced, that the mechanical powers of these bodies, if ever they had any, were destroyed previous to their exhibition.

Of late the action of poisons, like every thing else, has been explained upon what are called chemical principles. An immense number of animals have been subjected, wholesale, to lingering cruel torments, to procure facts which a little judgment, and a few well-directed experiments, would have demonstrated much better.

The philosopher who can read M. Orfila's work on poisons, and not be shocked at such wholesale cruelty, has learnt the counterpart of stoicism. It is not, however, quite so noble and glorious, to despise the pains and tortures we inflict upon the inferior and helpless beings whom accident has thrown into our power, as it is to despise the pains and accidents we are ourselves exposed to.

Before these experiments, and some others of the same kind, were made, it was well known that such bodies as had a strong chemical attraction for one or other of the elements of animal matter, would, when applied, decompose and destroy them. Hence all strong acids and alkalies would be chemical poisons, when swallowed in sufficient quantity.

It was well known that the human stomach is a tender thin membrane, of a peculiarly delicate internal structure; and particularly susceptible of being affected by stimulating applications. It was well known too, that the consequence of the application of stimuli is irritation or reaction, attended with inflammation, ulceration, suppuration, or gangrene, according to the nature and violence of the stimulus; and the peculiar structure of the part. It was known also that inflammation in the stomach, or small intestines, is not attended with the fever, and full pulse that is usually

produced when other membranous parts are inflamed, but with a different train of symptoms.

But most vegetable poisons, and the same remarks apply to animal poisons also, do not possess any observable chemical agency, nor are they direct stimulants. The poison of the viper was by the Abbé Fontana, after a long and close examination, compared to a solution of gum arabic. They must act by their influence upon the vitality of the stomach, or of the part to which they are applied, and, through the means of its nervous, or vascular communication, upon the vitality of the whole system. Such experiments as are directed with judgment to this important, but obscure point, leads to useful information, and thus affords an unction which may be applied to soften the feeling the cruelty excites.

That these poisons act in various and peculiar manners, that are not understood, upon the vital powers of animals, appears from the consideration that all animals are not affected in the same manner by the same poisons. Cantharides are poison to man and to many animals; and yet insects are occasionally found feeding upon them. Quassia is esteemed to be a simple bitter strengthening medicine, to man; yet to the whole genus of flies it is a deadly poison. Hemlock is poisonous to man; yet a goat eats it with impunity. Jalap is inert to a horse; yet to a man it is a drastic purgative.

The seeds of vegetables are various in shape, size, and composition. They all consist of four principal parts; any one of which being removed, the seed cannot germinate. Three of these parts are objects of the senses; these are the radix, the plumula, and the cotyledons.

A garden bean is generally produced as an example, on account of its magnitude, and of the facility with which it may be dissected.

When the skin of the bean is gently removed, leaving

what is called the eye, perfect; on gently separating the two lobes, they are found to be connected by means of a small light-coloured prominent body. This body is the embryo of the future vegetable. Very shortly after the growth has commenced, it clearly developes itself into the radicle and the plumule.

The broad bulky part of the bean is named the cotyledons. Every variety of seed almost is furnished with one or two of these cotyledons. These bodies have small vessels extending through them, that pass to the radicle: their use is to convey to the infant plant the nutriment required, until its parts are sufficiently developed to absorb and prepare its own nutriment.

The fourth essential part of the seed is not an object of sense; it is its vitality. It is produced, as well as the first material parts, from the parents; and is equally necessary to the production of the plant.

When a perfect seed is placed in a certain warm temperature, and has imbibed a certain degree of moisture, a change commences in it. The radicle becomes extended downwards, and soon throws off lateral branches in search of nutriment; the plumula slowly extends upwards, and after a time begins to evolve its leaves. It proceeds a very little way, however, before the presence of atmospheric air, or at least of oxygen becomes necessary; with which, if it be not supplied, vegetation stops. In general the air that passes through the soil is sufficient; and the vessels of the cotyledon enlarge, and, for a time, supply the radicle with nutriment. As this supply abates, the root becomes able to absorb the fluids of the soil it is placed in, and thus supply itself. The cotyledons now undergo a curious change. The office left them is to supply the nutriment absorbed by the root with oxygen, and to prepare it for continuing the growth of the plant until some of its leaves are developed.

The better to fit them for this office, they are themselves converted into leaves; thus forming the first, or seed-leaves of the young plant. They decay as soon as their office can be dispensed with.

The food or nutriment of plants, which is absorbed by the roots from the soil they are placed in, must be varied considerably for different vegetables. Hence the value of particular soils and situations for particular plants. Generally, a soil consists of sand, clay, calcareous earth, or loam, mixed with decaying vegetable matter, animal manures and water, in various proportions.

As the vegetable extends, its parts increase. Leaves are sent forth, branches form and extend: they are covered with bark, beneath which a woody matter gives them support. This is lined with a pith, and the whole are supplied with vessels, and covered with an epidermis.

As the growth proceeds, the vegetable increases in size, and the various plants are evolved more extensively. The liquid nutriment, absorbed by the roots, passes up to the leaves. In passing through them, it undergoes certain changes from the action of the oxygen in the air, to fit it for its final purpose; and then descends through the vessels of the bark, and is distributed to its respective destinations and functions.

The flower-buds are gradually developed. The organs of fructification at length appear; the petals expand; the stamina, the anthera, the pistils, the fruit with the seed, are successively perfected.

All these parts vary in matter, as well as in structure; and each part is sometimes composed of several proximate principles. These proximate principles vary also in the corresponding parts of different vegetables.

To point out these elements in detail would occupy volumes, and be very tedious.

All that can be attempted here is, a general description of those that are best known, classing as many of them as is possible under a few general heads.

Part 2. *Of Vegetable proximate Principles.*

We shall endeavour to explain them under the following articles.

1. Sugar
2. Gum
3. Cerasin
4. Mucus
5. Jelatine
6. Starch
7. Gluten
8. Albumen
9. Pollenin
10. Fibrin
11. Lignin
12. Ulmin
13. Suber
14. Cotton
15. Extractive
16. Bitter principle
17. Colouring matter
18. Indigo
19. Gum-resins
20. Resins
21. Balsams
22. Volatile Oils
23. Camphor
24. Fat Oils
25. Wax
26. Caoutchouc
27. Bird-lime
28. Tannin
29. Gallic Acid
30. Tartaric Acid
31. Oxalic Acid
32. Citric Acid
33. Malic Acid
34. Mucic Acid
35. Benzoic Acid
36. Other peculiar principles.

Article 1. Sugar.

Sugar is a well-known proximate principle of vegetables, which is easily soluble in water, generally crystallizable; when pure of a white colour, and of a pleasant sweet taste. It is produced in different proportions, and in different parts of a great number of vegetables. Sometimes it is in great abundance, in the sap generally; in some cases

confined to the roots or stem; but it is more particularly, and generally present in the nectarium, and the fruit.

The sugar of all vegetables is not the same; in some it is more soluble; in others the sweetness is more powerful: in some instances, the crystals are larger, and little disposed to deliquesce; in others the sugar may be reduced to a thick syrup, but cannot be made to crystallize.

We are best acquainted with the sugar produced from the sap of the sugar-cane. This plant is cultivated in great abundance, particularly in the East and West Indies. The plant is cut when the sap is richest in sugar, which is just previous to its blossoming, and the juice is pressed out by passing the cane between metallic rollers.

The juice of the East-India cane is the richest in sugar, of which it is said to afford nearly one-sixth: that of the West-Indies does not yield more than half as much. The juice is put into a large boiler and heated; a small portion of lime is added; a part of it is dissolved by the juice, and combines with any vegetable acid that may be present; but the greater part combines with, and coagulates the foreign herbaceous matter that is present, and rises with it in the form of scum. When the juice is sufficiently evaporated, which is accomplished by successively boiling it in different vessels, and adding lime-water as appears requisite, it crystallizes as it cools. When cold, holes are opened at the bottoms of the hogsheads or pots, into which it is put, and the molasses, or uncrystallizable part, is suffered to drain off.

The French and Portuguese purify the sugar still further, by what is called claying it. The sugar is poured from the cooler into conical pots, and when the molasses has drained off; the surface is covered with a layer of slightly porous clay and water. The water slowly percolates the sugar, carrying with it the remaining molasses.

Molasses, or treacle, has not been chemically investi-

gated. It appears to consist of an uncrystallizable variety of sugar, mixed with foreign bodies that communicate the dark colour to it.

Sugar is soluble to a certain extent in alkohol. It is capable of combining with acids, alkalies, and alkaline earths, and is decomposed by them.

It decomposes acetate of lead, combining with the oxide.

By a late analysis of Dr. Ure, it would appear to be constituted of carbon 5 atoms 30, oxygen 4 atoms 32, + hydrogen 4 atoms 4 ; = 66.

Article 2. Gum.

This proximate vegetable element is, like sugar, very well known in some of its varieties. It exudes from cracks in the bark of various trees, in the state of a transparent glutinous liquid, that gradually inspissates and hardens. The tree called mimosa nilotica, and some other species of the mimosa, produce gum arabic. The cherry tree, and many other trees, produce gums in a similar manner. The trees that produce gums are observed to possess an astringent bark.

Pure gum is soluble in water, producing an adhesive solution, which, on drying, reproduces the gum unchanged. The solution is not altered by keeping, except in hot situations; then, after a time, it becomes acid.

It is not much affected by saline bodies. Acids and alkalies, when concentrated, decompose it; when diluted, they unite with it without producing much change. The latter produce a slight precipitate. Silicated potassa produces a white flaky precipitate. Metallic salts scarcely affect it.

According to Dr. Ure's analysis, which appears to be one of the most correct, it is constituted of carbon 4 atoms 24, oxygen 5 atoms 40, + hydrogen 4 atoms 4 ; = 68.

Article 3. Cerasin.

Cerasin is very analogous to gum, and is often produced in mixture with it, and until pointed out by Dr. John, was usually confounded with it. Several of the gums appear to advance gradually from one principle to the other. Gum tragacanth is considered as a specimen of cerasin.

Bodies containing cerasin are hard to powder, and dissolve in water imperfectly. Gradually absorbing a large quantity of water, they swell and become soft, and form an elastic, more or less adhesive jelly; but not a perfect solution. It cannot, therefore, be mixed with a solution of gum arabic. It appears to be present with gum in the gum kettera, and some of the Senegal gums, and many of the plum-tree gums.

Article 4. Mucus.

This proximate principle of vegetables was first pointed out as a distinct principle from gum by Dr. Bostock.

Its solution in water is known as a glary adhesive fluid, resembling mucilage of gum arabic.

It exists abundantly in the different parts of various vegetables; in the seeds of the quince, and of flax, in the roots of saloop, lily, hyacinth, marshmallow, and common mallow, in most bulbous roots and fleshy leaves; in the numerous class of lichens, and in many other vegetables. It is readily obtained by boiling the bodies containing it for a short time, in from ten to twenty times their volume of water. The mucus from different vegetables is not quite similar. Good specimens are obtained in the seeds of the quince, and in linseed.

It is acted upon by nitric acid, nearly as gum is.

These three last named bodies are extensively used, and

promiscuously, by calico printers, and dressers of linens and cottons, for the same purposes as starch is used. They are frequently employed for particular indications in medicine, and medicated diet; and are wholesome nutritious substances.

Mucus is chiefly distinguished from gum by its precipitating acetate of lead, and permuriate of tin, while silicated potassa does not affect it.

Article 5. Jelatine.

Jelatine occurs chiefly in fruits, in which it is generally mixed with acids, sugar, and other proximate elements. Thus it is present in oranges, lemons, gooseberries, and currants. When the juice of currants is pressed off, and placed in a cool situation, it partly coagulates into a soft tremulous jelly, from which the more acrid and fluid liquid may be drawn off. It is soluble in hot water, but not in cold. It is destroyed by long boiling, and seems to be partly converted into mucilage.

Article 6. Starch.

Starch is a proximate vegetable element, which is produced in great abundance, in a great number of vegetables. It contributes largely to the volumes of many seeds and roots; and is by no means confined to those parts. The starches of different vegetables vary somewhat in their properties. A good specimen may be obtained by mixing flour of wheat into a stiff dough with water, and then continuing to wash it under a minute stream of water as long as the latter passes milky. The starch in a short time falls down, in the state of a white insoluble powder.

The manufacturer prepares it by soaking the unground

wheat in cold water; and when it is softened, pressing out from it the milky liquor. This process is repeated, the corn being in sacks, as long as the water is rendered milky. The starch falls to the bottom of the water, which dissolves the soluble part of the wheat, and retains some flocculi of gluten. This mixture soon begins to ferment, producing a portion of acetic acid and alkohol. In this state it dissolves the impurities of the starch, and leaves it of a brilliant clear white colour. The starch is then washed and dried. When dry it breaks into the irregular columnar crystals, or masses, that are characteristic of this body.

Starch is nearly devoid of taste and smell; when kept dry is not perishable. When wet with cold water, it falls into a light insoluble powder. With boiling water it unites into a stiffening jelly. When the quantity of water is large, the jelly partially subsides. When the jelly is evaporated to dryness, the starch is obtained in the state of an opaque brittle substance, which, in chemical properties, agrees nearly with the unboiled starch. When left in solution it shortly loses its gelatinous consistence, becoming mouldy and acid.

Starch combines with iodine, producing a violet blue colour, in various shades, according to the proportion, and black when iodine is in excess. The smallest proportion of iodine produces a perceptible blue colour, in a solution containing a small quantity of starch; so that these two bodies are excellent tests of each other.

Starch is not affected by alkohol, nor by ether. It does not even soften, nor lose the columnar form in either. It is little affected by neutral or metallic salts. It may be combined with tannin, and produces a precipitate which is soluble in water, so long as the temperature is preserved above 120°.

Potassa, in small proportion, seems to promote its solubility in water.

Starch is susceptible of being converted into sugar, by long boiling with diluted sulphuric acid.

One part of starch with twelve of water, after having been preserved for two years, was found partly decomposed, and a considerable quantity of sugar, gummy matter, and lignin produced.

In the process of malting, a considerable quantity of the starch of the barley is converted into sugar.

When starch is baked, it softens, swells, and becomes brown; and is converted into a substance used by calico-printers, under the name of British gum.

Concentrated acids decompose starch. Sulphuric acid dissolves it slowly, and evolves shortly a bulky charcoal, which renders the whole mass solid. It is imperfectly acted on by hot nitric acid, producing oxalic and malic, and perhaps acetic, acid.

According to Dr. Ure's analysis, it is constituted of carbon 5 atoms 30, oxygen 5 atoms 40, + hydrogen 4 atoms 4; = 74.

A great number of the seeds and roots in which starch is present, are used as food. Sago, tapioca, saloop, all contain a large proportion of it. Arrow-root is a pure starch.

Article 7. Gluten.

The tenacious elastic ductile mass which is left, after washing the starch out of wheat flour, is gluten. It is present, in great abundance, in various seeds, and other parts of vegetables. In the mass it is of a greyish colour. When spread out thin, it appears white and diaphanous. Exposed in this state to dry air, it dries into a hard brittle semitransparent cake; which, on being soaked in water, absorbs a part, becoming again tenacious and elastic. When exposed in a damp place, it becomes greasy and of-

fensive. It is slightly soluble in water. When heated, its properties are altered; it loses its elasticity and tenacity.

When fresh gluten is heated with alkohol, the spirit becomes milky, on adding water to it. By heating it with successive portions of alkohol, the whole of the soluble matter is removed. By slowly evaporating the alkohol, it is obtained in the solid state.

Mr. Taddey, who pointed out this mode of analysing gluten, called this body gliadine; and the insoluble portion left by the alkohol he called zimome.

Gliadine dries into thin brittle plates, which are yellow and diaphanous. When heated, it emits a smell similar to boiled apples. Its taste is sweetish; it is not soluble in water; but it is softened and rendered glutinous by it.

The zimome, which forms about one-third of the gluten, is of a whitish colour, and in a hard tough mass, or else in small incohesive globules, which become viscous on the addition of a little water.

It is heavier than water; when left to putrefy it exhales an urinous smell.

Both these bodies burn like animal matter.

Gluten, when left damp, soon begins to ferment, emitting carbonic acid and hydrogen. It soon obtains an acid smell, then an odour resembling that of cheese; it then becomes putrid, and at length is converted into ammonia, carbonic acid, and a kind of fat. It is precipitated from water by infusion of galls, also by chlorine. It is soluble in acetic and muriatic acid. Treated with nitric acid, it produces oxalic acid. Gluten and vegetables containing it, are very extensively used in food. It is the gluten contained in wheat that fits it so well for conversion into bread.

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Article 8. Albumen.

Vegetable albumen is very analogous to gluten, and appears to be very generally extended through vegetables. It exists in the green fecula of leaves, the young shoots of trees, and is particularly abundant in the cruciform plants. Mr. Seguin found it very abundant in those plants which gives out a liquid that will ferment readily into a vinous liquor, without the addition of yeast.

It is detected by heating the fresh clear liquid supposed to contain it, to 130°, or 160°, when it has the singular property of coagulating.

Vegetable albumen and gluten, like other vegetable proximate elements, are not uniform in their properties. In particular, they seem to merge in each other. Both contain nitrogen in their composition.

Article 9. Pollenin.

Pollenin is the name given by Dr. John to a proximate element, which he found in the pollen of various plants. The pollen of the lycopodium is considered as a good specimen of it. It is yellow, free from taste and smell. It takes fire readily, burning rapidly with a bright flame; and is often used for theatrical lightning. It is not soluble in water, alkohol, ether, volatile nor fined oils. But it will ferment, emitting the smell of cheese and ammonia, and at length putrefy.

Article 10. Fibrine.

A substance very analogous to animal fibrine is met with exuding from the papaw tree, a native of the Isle of France, and some parts of South America. It has some analogy to gluten, but a still closer analogy to the fibrine of blood.

M. M. Humboldt and Bonpland first described a tree growing on the northern declivities of the Andes, that yielded on the bark being wounded, a considerable quantity of an agreeable nutritious juice analogous to milk. This juice on warming it separates into a fusible wax like substance; and an infusible fibrous matter resembling fibrine in many of its properties.

Article 11. Lignin.

Lignin is the proximate element which chiefly constitutes the wood of trees. It appears to vary more in different trees, in structure and texture, than in chemical constitution. When a piece of wood is macerated in water, and then in alkohol, until all its soluble parts are removed; it may be considered as pure lignin. The properties of different woods are well known. Diluted acids dissolve wood slowly. When concentrated they decompose it The action of fire on wood, in the open air, is seen daily. When exposed to a red heat in close vessels, it yields a quantity of acetic acid, mixed with an offensive empyreumatic oil, and a black charcoal possessing the exact structure of the wood is left in the retort.

When wood is heated with nitric acid, it is converted into oxalic acid chiefly; and some citric and carbonic acids.

Hemp, a variety of lignen, or the dried saw-dust of hornbean, produces, when heated with sulphuric acid, a substance that resembles gum.

In its ultimate elements, lignin is supposed to consist of nearly oxygen 4 atoms 32, hydrogen 4 atoms 4, + carbon 7 atoms 42; = 78.

Article 12. Ulmin.

This body was named ulmin from its being first observed

in the bark of the elm. According to M. Berzelius it exists in the bark of most trees. When the bark has been digested in alkohol, and subsequently in cold water, the ulmin may be obtained tolerably pure, by macerating it in hot water.

It has little taste or smell, is of a dark brown colour, and very sparingly soluble in water, or in alkohol. It is soluble in a weak solution of carbonate of potassa. It is precipitated by acids, and by sulphate of iron. When heated it swells and burns without melting.

Article 13. Suber.

Suber is the name given to the peculiar substance which constitutes the outer bark of the quercus suber. This is the common cork, a peculiar vegetable product different from any other. It appears to be a variety of a substance that forms, in mixture with other proximate principles, the epidermis of most barks.

It is soft, light, elastic, and burns with a bright flame, leaving a bulky charcoal. Nitric acid decomposes it, producing a peculiar acid called suberic acid, a kind of wax, artificial tannin, and a kind of starch.

Article 14. Cotton.

Cotton is the produce of the several species of the gossypium, and of some other plants, the seeds of which are enveloped by it.

Its physical properties are well known; more than one thousand tons being consumed annually in this country.

Little is known of its chemical properties. It has an attraction for alumina, oxide of iron, and some other metallic oxides, and also for tannin. By virtue of these attractions different colouring matters are fixed on it.

Nitric acid decomposes it, producing among other bodies oxalic acid.

Dr. Ure represents it as constituted of carbon 11 atoms 66, hydrogen 8 atoms 8, + oxygen 10 atoms 80; = 154.

Article 15. Extractive,

Or extract, is a term applied to all the matter obtained by boiling any part of a vegetable in water, and evaporating the strained liquor to the consistence of thick treacle. The various vegetable principles, as they were pointed out, have been successively excluded from it, and names appropriated to them.

It is now considered as a substance soluble in water, varying in taste according to the vegetable producing it; more or less soluble in alkohol, and not in ether; and throwing down opaque flocculi if boiled long in water, in consequence, it is supposed, of its absorbing oxygen.

The extract prepared in this manner from saffron was considered as an example of very pure extractive; and has the most distinguishing properties imputed to extractive. It was pointed out as a distinct element, under the name of polychroite, by M. Lagrange; chiefly on account of its peculiar colour, and the changes it undergoes from chemical re-agents.

Extract is precipitated by chlorine, it combines with alumina into an insoluble compound. The same with the alkalies, and most of the metallic oxides.

The extracts prepared for medical use contain all the soluble parts of the drug which are not volatile, and can be extracted by decoction in water, sometimes by the help of alkohol; the clear strained liquor being gently evaporated, until the matter extracted is obtained in the solid state.

Article 16. Bitter Principle.

Since the property of exciting in the human palate, the sensation or taste we call bitter, may be produced, as the sensation we call sweet is, by very different elements or combinations of elements; that is, since it is a simple property in certain bodies necessarily resulting from them in common with other properties, it is not a very appropriate term, any more than the last, for a substance. There are, however, a considerable number of vegetables that give out a strong bitter taste to water in which they are infused. They are found to agree also, to a certain extent, in many of their sensible, chemical, and frequently in their medicinal properties; though upon examination they are found to vary in other

Article 17. Colouring Matter.

There is another collection of proximate elements, called by chemists, from the uses they are chiefly applied to, colouring matters.

They agree in having an attraction for certain bodies and in changing their colours.

Little attention has been paid to most of them, except as colouring drugs; and to the different modes, and manipulations necessary to fix or improve their respective colours.

Vegetable bodies are used very extensively, both as dyes, and as pigments.

The colour of dyes is fixed upon the substance to be coloured, by virtue of their mutual attractions for each other; or else by the introduction of alumina, or some other body that has a strong attraction for both, the fabric and the colouring matter. This intermediate body then fixes the colour, and is in consequence called the mordant.

Pigments or paints are, as we know, merely thin mechanical coverings.

When vegetable and animal colours are used as pigments, they generally require to be united to some opaque substance, that shall give them body and volume. For this purpose they are generally united to alumina; an earth for which most of the soluble vegetable elements have a strong attraction. Hence alumina forms the substantial basis of the various lakes. Chalk, carbonate of lead, and other bodies are sometimes used for the same purpose.

Article 18. Indigo.

Indigo is employed as a blue dye. It may be obtained from several plants growing in both the Indies; but it is chiefly obtained, by the manufacturer, from the plants called Nerium Tinctorium, Indigofera Tinctoria, Indigofera Guatimala, and from the Indigofera Argentea, which produces a superior indigo, but in smaller proportion.

A large quantity of the plant is steeped in as much water as rises four or five inches above it. Here it ferments for a certain precise time, pointed out by experience. The water becomes opaque, of a green colour, exhaling carbonic acid and ammonia. At a certain time the liquor is drawn off into a second cistern, and agitated until it assumes a curdled appearance. Lime-water is now added, and the blue matter left to subside. The water is then drawn off, and the indigo, being first drained in bags, is dried in the shade.

Indigo is a light substance, of a compact friable texture, having a copper, violet or blue shade on its surface. When powdered, it is of a fine deep blue colour.

The indigo, as thus prepared, is a mixture of several proximate elements, and some earths; about half of it is pure indigo.

Pure indigo is volatile, subliming in the state of a blueish

crimson vapour, and condensing into crystals. It is insoluble in water. Dissolved in concentrated sulphuric acid, it forms the Saxon or liquid blue. Chlorine destroys its colour.

It is extensively used for dyeing, for which purpose it is necessary to render it soluble in water. Dyers accomplish this by mixing, in a sufficient quantity of water, one part of indigo, two parts of protosulphate of iron, and as much lime. Part of the lime decomposes the sulphate of iron, and the protoxide of iron thus produced, as it precipitates, attracts a portion of oxygen from the indigo, thus rendering the indigo soluble in the lime-water that is formed. The material now dipped into it, is stained green; but on washing it in water containing a little sulphuric acid, it is cleared from the lime and peroxide of iron; and, on exposure to the air, the indigo again absorbs its due proportion of oxygen, and communicates to the fabric a permanent blue colour.

According to the ultimate analysis of Dr. Thomson, pure indigo is constituted of carbon 7 atoms 42, oxygen 2 atoms 16, hydrogen 6 atoms 6, + nitrogen 1 atom 14; = 78.

Article 19. Gum-resins.

Gum-resins are a class of bodies that differ much from each other, and most of them are mixtures of various substances. Generally they have an unpleasant smell, a nauseous acrid taste; are solid, when dry brittle, and of various, frequently of mixed, colours. When heated, they soften, and at length burn.

When triturated with water, they produce milky solutions. Alkohol dissolves a part of them, to which, when water is added, a permanent milky solution is produced. They are partially soluble in vinegar, and in wine; they are soluble in alkaline solutions also. Some of them are converted into tannin by the action of sulphuric or nitric acids.

Such of them as have been analysed appear to produce from two to four parts of a resinous, and one of a gummy, substance. Many of them contain a volatile oil, and one or more of the known vegetable elements, more or less perfectly mixed.

Under this head may be included among others ammoniacum, assafœtida, olibanum, galbanum, sagapenum, myrrh, opoponax, bdellium, euphorbium, gamboge, &c. This last named substance consists of one part of pure gum, and four of a peculiar resinous matter, soluble in alkohol, that communicates to marble and porous bodies a stain of a fine yellow colour. It is a violent cathartic when taken medicinally.

Article 20. Resins.

These are another numerous class of bodies, that have their respective peculiar properties, and are, in consequence, adapted to different uses. Many of them are composed of two or more peculiar vegetable elements.

They are solid, brittle, transparent bodies, generally light coloured. They break with a glassy fracture, are brittle, and more or less hard. They are negatively electric, fusible, and very inflammable; varying in specific gravity, but are somewhat heavier than water.

They are insoluble in water, most of them are soluble in alkohol, and some of them in fixed oils, in essential oils, also in ether, and in acetic acid. They are soluble in alkalies, and may be introduced into soaps, of which common yellow soap is an instance. They are decomposed by acids, and tannin produced.

Many of the resins are used in medicine. The following are used chiefly in varnishes: elemi, animi copal, rosin, mastich, resin of juniper, lac. For this use they are dissolved, according to their properties, in alkohol, oil of turpentine, or

of lavender, in drying oils, or in mixtures of drying and essential oils.

They are constituted, generally speaking, of carbon from 65 to 80 parts per cent., hydrogen 7 to 12, oxygen 11 to 27.

Lac is the production of a small insect, which deposits its egg, surrounded with this substance, upon the branches of certain trees in Hindostan, and its vicinity. It comes into England in the state of stick, seed, and shell lac.

The stick lac is a mixture of about 68 or 70 parts of a peculiar hard resin, 10 of red colouring matter, 6 of wax, and nearly as much gluten, with 7 or 8 per cent. of other bodies, according to the analysis of Mr. Ha'chett. It contains a small quantity of a peculiar acid also.

A large proportion of the stick lac is broken up in India, and the colouring matter removed for dyeing, while the resin is sent into Europe, in its broken state, or melted and spread out, in the state of shell lac.

It readily dissolves in alkohol, and is the substance or basis of all the brown spirit varnishes and lackers. It is the basis also of all the best sealing waxes. In India, it is formed into various trinkets,

Article 21. Balsams.

Many of the resinous bodies are known by the name of balsams. This term appears to have been originally applied to those resinous bodies which have not acquired a solid state. Such are balsam of Gilead, Canadian balsam, balsam of Peru, of tolu, and of copaiba. These bodies agree with resins in their general properties, consistence excepted. Of late it has been a fashion to change the meaning of this word, and apply it to those resinous substances which, on the application of heat, yield benzoic acid. According to this distinction, benzoin, storax, balsam of Peru and tolu, are the only true balsams.

Guaiacum has most of the properties of a resin, but it yields oxalic acid, and not tannin, when decomposed by nitric acid. It is peculiar in this also, that its powder, on being exposed for a time to the light, assumes a green tint.

Dragon's blood is a peculiar body, which is insoluble in water, and soluble in alkohol, to which it communicates its colour. This body is nearly free from taste as well as smell. It is brittle, dull, and opaque. When heated, it readily takes fire, and burns with a slightly fragrant smell. It has been *supposed* to emit benzoic acid.

When heated with nitric acid, it is decomposed, and tannin and benzoic acid obtained from the solution.

Article 22. Volatile Oils.

Volatile oils are existent in different parts of a great number of vegetables. They are volatile, and are usually separated from the respective vegetables by distillation with water; but the essential oils of lemon, orange, bergamotte, and citron, are obtained by expressing the outer rind, on the surface of which they are contained in small cells.

Volatile oils have a pungent taste, and a penetrating smell, peculiar to the vegetable they are drawn from; and which is in most cases grateful. Their colour is generally a very pale brownish tint. They are volatilized at about 212° or a little more, and they are highly inflammable. When dropped upon paper and held to the fire, they wholly evaporate in the air without leaving any stain.

Their specific gravity varies; some of them are heavier than water, but in general they are lighter.

They are sparingly soluble in water; readily so in alkohol. When long preserved and exposed to air and light they grow thick and resinous; but some undergo this change much more readily than others. They are decom-

posed by nitric and sulphuric acids: these acids, when concentrated, sometimes inflame them. Chlorine and muriatic acid combines with some volatile oils, producing a substance which resembles camphor. The liquids usually called essences are strong solutions of essential oils in alkohol; and are frequently more convenient for use than the pure essential oils.

Article 23. Camphor.

This substance comes chiefly from Japan, in a rough state. It is said to be the product of the camphor laurel. It is produced, however, from various other vegetables also, and is sometimes found in their essential oils. The rough camphor is purified by sublimation. It is white, crystalline, brittlish, and slightly ductile. It has a peculiar well-known odour, and a hot acrid taste. Its specific gravity is about 0.99. When exposed to the air at the usual temperature, it wholly evaporates. It melts at about 288°, and boils at 400°. It sublimes in close vessels, and is condensed into hexagonal crystals. It is very sparingly soluble in water. It is soluble in alkohol, in almost any proportion, and is precipitated by the addition of water. When the water is added very slowly, small feathery crystals appear. It is abundantly soluble in fat and volatile oils. Various acids, if not too concentrated, dissolve camphor without decomposing it. Concentrated sulphuric acid decomposes it into charcoal, a resinous matter approaching to tannin, and a little yellow oil. Nitric acid converts it into a peculiar acid called the camphoric.

According to Dr. Ure's experiments, it is constituted of carbon 10 atoms 60, hydrogen 9 atoms 9, + oxygen 1 atom 8; = 77.

Varieties of camphor have been obtained from several essential oils.

Article 24. Fat Oils.

Fat oils are found chiefly in the seeds of certain vegetables. The oil is confined, for the most part, to some of those seeds having two cotyledons. Sometimes, as in the olive, it is present in the pulp, surrounding the stone which contains the seed. These oily seeds form emulsions when triturated with water. The oils are obtained generally by strong pressure, sometimes by boiling in water. Their general sensible properties are very well known. They give a greasy stain, which does not evaporate by heat. Their specific gravity varies a little, but they are all lighter than water.

They are insoluble in pure water; and in general are sparingly soluble in alkohol, which, however, dissolves castor oil in almost any proportion. They are soluble in sulphuric ether.

Some of these oils, olive oil in particular, coagulates in part, even in a moderate degree of cold, and thus may readily be separated into two parts by filtration. M. Chevreuil, who has laboured a great deal in the analysis of fats and oils, has found that these oils, and fats in general, are constituted of two principles, which are mixed in different proportions, in different oils: he names them stearine and elaine.

Stearine is harder, fuses at about 100°, and is less soluble in hot alkohol, from which it separates as it cools in silky crystals. The elaine coagulates at about 45°, or lower in some cases; is more soluble in hot alkohol, and separates from it in an oily state.

According to M. Chevreuil these two bodies are united in varying proportions, in all fats and oils, whether animal or vegetable. Some fluid oils consist almost wholly of elaine; and hard fats contain a large proportion of stearine.

Olive oil contains in general about 28 parts of stearine to 72 of elaine.

These oils dissolve sulphur and phosphorus. They are not volatile; but when heated to about 500°, they begin to be decomposed, giving off an inflammable vapour: at 600° they boil, and are rapidly decomposed into an offensive oil, and permanent gasses. As the temperature rises, the quantity of permanent gas increases.

These oils are, as is well known, very combustible.

Several of them, linseed oil for instance, nut oil, and poppy oil, have the property of drying when spread out exposed to the air; and hence are employed in painting. This drying property is improved by boiling them, and mixing with them certain oxides and metallic salts. They are used in the preparation of printers' ink, and of several varnishes.

The concentrated acids decompose them, sometimes exciting inflammation.

When mixed with light charcoal, dry cotton, wool, or flax, as when the latter substances have been used to wipe the waste oil from machinery, and then thrown together in considerable quantity, the mass has heated, and at length inflamed. Destructive fires have been produced by it.

Vegetable oils, and animal fats also, combine readily with alkalies, alkaline earths and oxides. With the former, they produce our perfect soaps, which are so extensively used, and such valuable detergents; with the latter, insoluble imperfect soaps or plasters.

In the formation of soaps, it appears that the two principles of fat above-mentioned, the stearine, and the elaine, both suffer a change to enable them to combine with alkalies. So that when these soaps are again decomposed, the fat is altered in its properties, and a small quantity of what is called a sweet principle is produced. Those saponified fats, like the principles they are produced from, differ in

properties; and the same chemist has named them from the physical properties, and from their capability of producing definite compounds with various bases, margaric or pearly, and oleic or oily acids.

Their respective compounds, or soaps with soda, are harder than those with potassa. Soft soaps are composed of potassa, and those oils which contain a large proportion of elaine: hard soaps are composed of soda and olive oil, or those fats which contain a large proportion of stearine.

The margaric and oleic acids are rather less fusible than the fats they are produced from, and are freely soluble in boiling alkohol. They colour litmus paper red, and combine with various alkaline, earthy, and metallic oxide bases.

The soaps of this country are, generally, combinations of an alkali with animal fat. But the best and most perfect hard soap, as the Castile soap, is made from olive oil and pure soda. Soda is the alkali which must be combined with oils, and animal fats also to produce hard soap. Soft soap is commonly prepared from potash and fish oils, or soft fats; but even with hard fats a soft kind of soap is produced with this alkali.

When hard soap is to be produced by the assistance of potash leys, it is necessary, after the alkali and potash are combined, to add a certain quantity of muriate of soda. A double decomposition is produced, the potassa leaves the tallow, and combines with the muriatic acid; and the soda leaves the muriatic acid to combine with the principles of the tallow.

The soapy compound has a strong attraction for a certain proportion of water.

Good dry Castile soap is generally composed of soda 9, oil 76, water 15.

Good English tallow soap is more variable, containing in 100 parts, soda from 6.5 to 8, tallow from 60 to 65, water 30 to 33.

Soap is soluble in alkohol. When alkohol is slowly evaporated, the soap is left in the state of a solid transparent mass.

The proportions of the elements in the constitution of vegetable oils, of course varies to a limited extent. According to M. M. Gay-Lussac and Thenard, olive oil consists of

Carbon .	77.2	which approaches to	10 atoms,	60
Oxygen .	9.5	. . . . .	1 atom,	8 =79
Hydrogen	13.3	. . . . .	11 atoms,	11

to produce each supposed atom of the oil.

Article 25. Wax.

Wax, similar to bees'-wax, may be obtained from the surface of almost all leaves, to which it forms a natural varnish, defending the upper surface from the action of water; and in some vegetables it is met with in considerable abundance.

It may be obtained by macerating the bruised leaves in water first, then in alkohol; to abstract those parts which are soluble in these liquids; and then pouring over the residuum four or five times its weight of a solution of ammonia. After macerating for some time, diluted sulphuric acid may be slowly added to a small excess, and a yellow powder falls down, which is the wax.

When purified by bleaching, it is white. It melts at 155°. At a high temperature, it is decomposed and evaporates. When inflamed it burns with a very bright flame. It is free from the peculiar greasy feel of fats and tallow. Boiling alkohol acts upon it: by means of this agent, Dr. John divided wax into two substances, which he named cerin, and myricin.

Cerin he describes as being soluble in fixed and volatile oils, separating from the latter in greasy-looking grains, insoluble in water; soluble in hot alkohol and ether, but

separating from them as the solution cools. Its consistence is that of wax. Its specific gravity is 1. It melts below 140°. It unites with alkalies, forming soaps.

Myricin he describes as insoluble in water, ether, or alkohol, even when heated. Soluble in fixed and volatile oils, liquefiable below 140°. Of the consistence of wax, but rather glutinous; its specific gravity about 0.9.

Wax may be melted in fixed oils, and in most volatile oils. It forms a soap with alkalies. Punic wax, formerly used in encaustic paintings, was composed, according to Mr. Lorgna, of wax twenty parts, soda one part.

Chlorine gas and acids, have little or no action upon wax.

It is observed that fat oils, by long exposure to the air, and by the action of chlorine upon them, and of some acids, become hardened, and more resembling wax; and this change is supposed to be consequent upon their combining with a further proportion of oxygen. Hence it is supposed by some chemists, that wax is produced by a similar process. The results of the best analyses we have been favoured with, however, do not confirm this supposition.

By the analysis of Gay-Lussac and Thenard, it consists of carbon 81.784, hydrogen 12.672, oxygen 5.544, in 100 parts.

Article 26. Caoutchouc.

The well-known substance called Indian-rubber, or elastic gum, is another vegetable principle frequently met with. But it is, generally, more or less mixed and disguised with other bodies. It is produced in tolerable purity in several trees in South America, and in India. It appears that upon the tree being wounded, a milky juice exudes, which on exposure gradually becomes solid.

When pure it is white, free from taste and smell, and

peculiarly elastic. The caoutchouc bottles are formed by spreading repeated layers of the yet liquid juice over moulds of clay, and drying them by a gentle heat; during which the smoke colours them. This substance is not affected by air, nor by water. It is softened by heat, or by hot water. Two pieces that are heated considerably, may be pressed together into one, by a continuance of the heat and pressure. This is, perhaps, the best way of giving it any peculiar form.

It is insoluble in alkohol, and in fresh ether. But when the ether has been washed with water, it retains about one-tenth of the latter liquid, and then dissolves the caoutchouc. On the application of heat, the ether evaporates, leaving it unaltered; but rather adhesive.

It is soluble in boiling oils, but it dries again into a more or less glutinous body. It is dissolved by the rectified petroleum obtained from the distillation of coal. It is but slightly acted upon by alkalies or acids, unless they are concentrated.

When heat is applied so strongly as to melt it, a partial decomposition is produced; and it does not recover its consistence and elasticity. When inflamed, it burns with a bright flame, and emits an unpleasant smell.

According to Dr. Ure's analysis, it consists of carbon 90, hydrogen 9.11, oxygen 0.88. Its mechanical properties render it convenient for a number of well-known purposes. Patent water-proof cloth is prepared by spreading a solution of caoutchouc in petroleum over two surfaces of cloth, pressing them together and drying them. Hats are sometimes rendered water-proof by working this solution into the felt.

Article 27. Birdlime

Is a viscid substance, which exists in the bark of some

trees. It is usually obtained by macerating and fermenting the middle bark of the holly, which is thus converted into a similar substance.

It is very viscid and tenacious; it softens on handling; has little taste or smell. When heated it melts, swells, and inflames. In the air it continues soft for a long time, and never properly hardens. It is soluble in ether, and in oils. Concentrated acids and alkalies decompose it.

Article 28. Tannin.

This is a valuable proximate principle, on account of its properties of tanning skins, and converting them into leather. It exists in the barks of a great number of vegetables, and in the woods of many. It is difficult to obtain it pure; but, like other vegetable principles, it varies according to the vegetable it is obtained from.

When the catechu of the druggist is powdered, and macerated in water, at a low temperature, the liquid strained, evaporated for a time, filtered when cold, and evaporated again nearly to dryness; on dissolving the product in water, a tolerably pure tannin is obtained.

It is a dark brown, brittle substance, having an astringent, bitter taste. It is soluble in water, and the solution does not change, nor become putrid by keeping. It is soluble in weak alkohol.

It is precipitated by most acids. Chlorine, and nitric acid decompose it. It combines with the alkaline carbonates, and with lime from lime-water: it is precipitated also by muriate of alumina, muriate of tin, and, with many of the other metallic oxides. But its most valuable property is that of producing an insoluble compound with animal gelatine and albumen; upon the application of which property, we are dependant for all tanned leather.

The average quantity of tan that may be obtained from

480 pounds of different barks, is thus stated by Sir H. Davy.

Of the bark of middle size Oak, cut in spring,	29 pounds.
Spanish Chesnut	21
Large size Leicester Willow	33
Elm	13
Large common Willow	11
Ash	16
Beech	10
Horse Chesnut	9
Sycamore	11
Lombardy Poplar	15
Birch	8
Hasle	14
Blackthorn	16
Coppice Oak	32
Oak, cut in autumn	21
Larch, cut in autumn	8
Of white internal cortical layers of Oak Bark	72

Mr. Hatchett has pointed out a manner of preparing an artificial tannin, by macerating charcoal in diluted nitric acid. The charcoal is at length dissolved, and a brown liquid is produced which furnishes, from five parts of charcoal, six of tannin.

This artificial tannin does not exactly resemble the natural, but it agrees in the valuable property of *forming* an insoluble compound with animal gelatine. When gelatine is precipitated by this tannin, according to Mr. Hatchett, the compound is constituted of, gelatine 64, tannin 36.

Several of the mineral acids are found in vegetables, the sulphuric for instance, the muriatic, the nitric, the phosphoric, the hydrocyanic, and the carbonic: the four *first* are rarely, if ever, met with, except in a neutralized state. A considerable number of peculiar acids are also found, which are of native vegetable growth. Some of these can-

not be produced by art: others may be artificially produced. Such of them as have been investigated are definite chemical compounds, and are uniform in their properties.

Article 29. Gallic Acid.

Gallic acid is contained in various astringent vegetables. It is so intimately mixed with tannin and extractive matter, that it is very difficult to obtain it in tolerable purity.

The most ready way of obtaining it is, perhaps, that of Mr. Fiedler. Boil 1oz. of powdered galls in 16oz. of water to 8oz. and strain. Dissolve 2oz. of alum in water, precipitate by carbonate of potassa, wash the precipitate repeatedly, and add it to the decoction, stirring it frequently during about twenty-four hours. Then filter and wash the sediment until the washings no longer colour sulphate of iron. Evaporate this solution, and the gallic acid will crystallize in small white needle-like crystals, of an acid astringent taste. They may be sublimed by heat, and condensed in crystalline plates. They exhale a peculiar odour when heated. They are soluble in about twenty parts of cold water, or three of boiling water. They are soluble in alkohol, and in ether.

Gallic acid is converted into oxalic, by the action of nitric acid.

It forms soluble compounds with alkalies, and precipitates most of the metallic solutions; iron, of a deep purple black; mercury, orange-yellow; gold, silver, and copper, brown; bismuth, lemon-colour; lead, white.

The infusion of galls, which is chiefly a compound of gallic acid and tannin, is extensively used in the production of a black dye, and in the formation of writing ink, in consequence of its property of precipitating sulphate of iron of a deep purple black, which colour becomes more intense on exposure to air.

There are numerous formulæ for the preparation of ink; of which the underwritten is as good, perhaps, as any.

Boil one ounce and a half of logwood slowly in three pints and a half of water down to three pints; strain the liquor, and add to it bruised galls four ounces and a half, gum arabic two ounces, sulphate of iron one ounce and a half, cloves one drachm. If shaken daily it may be used in a fortnight. All inks may be decomposed, and the colour destroyed by chemical agency.

Infusion of galls is one of the most valuable tests of iron in delicate chemical analysis.

Article 30. Tartaric Acid.

Tartaric Acid is, perhaps, the most abundant of the vegetable acids that is met with ready formed. It is the principal acid in grapes, and exists in the juices of many other fruits, and other parts of vegetables.

It is usually obtained from common tartar, which is an impure bitartrate of potassa. This substance falls down in abundance from new wine; and is gathered from the sides and bottoms of the vessels. When purified, and recrystallized, it is known under the name of cream of tartar. To obtain the acid, ten parts of cream of tartar are to be saturated with three parts of chalk. The insoluble tartrate of lime that falls down, is washed and diffused in water; and as much sulphuric acid added as equals the weight of the chalk employed. After frequently stirring the mixture during twenty-four hours, decant, or filter and evaporate until nearly dry: re-dissolve, in about six times its weight of water, filter, and after evaporating again to nearly one half, set the solution to crystallize.

This acid is soluble in six parts of cold water, and has an agreeable acid taste. According to Dr. Ure, its constitu-

ents are, carbon 4 atoms 24, hydrogen 2 atoms 2, + oxygen 5 atoms 40; = 66.

The crystals are composed of about 11.25 water and 88.75 acid.

Tartaric acid combines with alkalies, earths, and oxides, producing crystallizable salts. With many metallic oxides it forms salts, from which the oxides are not precipitated by alkalies, their carbonates, nor their succinates; but soluble double salts appear to be produced. This is the case with magnesia, alumina, oxides of iron, lead, manganese, titanium, antimony, nickel, and cobalt.

Its principal saline compounds that are used are

1. *Tartrate of Ammonia.* It forms soluble crystals of a cooling taste. The further addition of acid, produces a difficultly soluble tartrate.

2. *Tartrate of Potassa,* or soluble tartar, is formed by saturating cream of tartar with carbonate of potassa. This salt crystallizes in four-sided prisms, soluble in twice their weight of water. It is usually sold in a granulated state, containing less water than the regular crystals.

3. Bitartrate of potassa is the *cream of tartar* already spoken of. It has an acid, somewhat earthy taste. It is soluble in thirty parts of boiling water, or four times as much of cold. When exposed to a red heat, the acid is decomposed, and a carbonate produced.

4. Tartrate of potassa and ammonia is obtained by neutrallizing cream of tartar with carbonate of ammonia.

An efflorescent salt is produced, from which the ammonia escapes by the action of the atmosphere.

5. Tartrate and bitartrate of soda both form very soluble crystals.

6. Tartrate of potassa and soda, or *Rochelle salts,* is prepared by saturating cream of tartar with carbonate of soda. It forms clear handsome prismatic crystals, soluble in about five parts of cold water.

It consists of tartar of potassa 54, tartrate of soda 46; or acid 2 atoms, potassa 1 atom, soda 1 atom.

7. Tartrate of lime, of potassa and lime, of baryta, and of strontia, are nearly insoluble. Tartaric acid precipitates sulphate of magnesia. Tartrate of magnesia, when the acid is in excess, forms a crystallizable salt.

8. Tartrate of potassa and iron is used, in medicine, as a tonic.

9. *Tartrate of Potassa and Antimony*, or emetic tartar. The antimonium tartarizatum of the London Pharmacopœia, crystallizes in regular white octoedral and tetraedral crystals, soluble in three parts of boiling, or fourteen of cold water. It appears to consist of tartaric acid 2 atoms, protoxide of antimony 1 atom, potassa 1 atom.

The other combinations of tartaric acid are seldom used.

Article 31. Oxalic Acid.

This acid has been found in some fruits, and in the roots, leaves, and barks of many vegetables, particularly in the leaves of common sorrel. It is obtained most readily by decomposing sugar with nitric acid.

When to one part of sugar, four parts of nitric acid, and two of water, are added in a retort, the sugar dissolves, and nitric oxide gas is evolved. When about one-third of the acid is distilled over, the compound may be poured into a shallow vessel, and left for two or three days to crystallize. Upon further evaporating the mother liquor, more crystals are obtainable. By this process, rather more than half an ounce of oxalic acid may be procured. It may be dissolved in water, and re-crystallized.

It crystallizes in small flattened quadrangular prisms, transparent, and very acid to the taste. One grain dissolved in half a pint of water, renders it sensibly acid.

By Dr. Ure's analysis, this acid is constituted of carbon 19.13, or 2 atoms 12; hydrogen 4.76, or 3 atoms 3; + oxygen

76.2, or 6 atoms 48; = 63. The crystals consist of 52 acid, and 48 of water.

When, however, this acid is wholly deprived of water, for it appears to lose three atoms of water in combining to form oxalate of lead, it consists of carbon 2 atoms 12, + oxygen 3 atoms 24; = 36; a fact that appears to have been first pointed out by Doebereiner.

This acid combines extensively with alkalies, earths, and oxides, forming crystallizable salts, varying in solubility.

Oxalate of ammonia crystallizes in prisms, soluble in about eighteen parts of water. This salt is used as a test for lime.

There is an oxalate of potassa, a binoxalate, and a quadroxalate; this latter salt exists in wood sorrel. The other salts are little used.

Oxalate of lime is insoluble, both in water and in excess of oxalic acid. It is soluble in muriatic and in nitric acids. It consists of oxalic acid 1 atom 36,+ lime 1 atom 28; = 64.

This acid decomposes the compounds of peroxide of iron, and dissolves the oxide. It is, in consequence, useful for removing iron-moulds or ink stains.

From inattention this acid is sometimes swallowed instead of Epsom salts. The mistake may be instantly discovered from its pungent acid taste. A mixture of whitening, or chalk and water, should be swallowed as fast as possible, and then be evacuated by vomitting. If this remedy be swallowed in time, it will prevent any fatal consequences.

Article 32. Citric Acid.

This acid is found in great abundance in the lemon, orange, lime, and citron. It is mixed in the juice of several other fruits also, and in some other parts of particular vegetables.

It may be obtained pure, by saturating the juice of the lemon or lime with pure chalk; washing the insoluble citrate of lime with water, and decomposing it with as much sulphuric acid as equals the chalk in weight, but previously diluted with ten parts of water. After repeated agitation during twenty-four hours, let the sulphate of lime settle, and decant the clear liquor, washing the precipitate to obtain all the acid. Evaporate the liquor to about one-fourth; separate the remaining sulphate of lime, and continue the evaporation until the liquor is growing syrupy; then set it aside to crystallize. By evaporating the mother liquor again, more crystals may be obtained, which will be dark-coloured, and must be purified by dissolving, and crystallizing them as often as may be necessary.

The average quantity of crystals obtained from one gallon of good lemon-juice, may be estimated at eight ounces, but frequently it does not exceed six ounces.

According to Dr. Ure, crystallized citric acid is constituted of carbon 33, or 4 atoms 24; hydrogen 4.63, or 3 atoms 3; + oxygen 62.37, or 5 atoms 40; = 67 atoms.

But about one-quarter of this acid is water, and separates in forming dry citrates: so that, according to this estimate, the pure acid must consist of carbon 4 atoms 24, hydrogen 1 atom 1, + oxygen 3 atoms 24; = 49.

Citric acid is in white, rhomboidal, or pyramidal crystals, of a pleasant acid taste. They may be distinguished from tartaric acid, by dissolving, in rather less than their weight of water at 60°, by not producing a precipitate on the cautious addition of carbonate of potassa, and by a slight tendency to deliquesce.

It combines with all the alkalies, earths, and oxides. Citrate of potassa, and of ammonia, are compounds used chiefly in medicine. Of the crystallized acid, thirty-six grains neutralize sixty of the bicarbonate of potassa, or forty-four grains of subcarbonate of ammonia. Both these

salts are difficult to crystallize, very soluble, and deliquescent. The same quantity of acid saturates forty grains of subcarbonate of magnesia, eighteen grains of lime, and thirty-six grains of common levigated chalk. This acid is used in certain processes of calico printing.

Article 33. Malic Acid.

Malic acid is another vegetable acid, which is found in various fruits. Apples, plums, sloes, barberries, and the elder berries, owe their acidity to it. The gooseberry, the currant, the cherry, the raspberry, the strawberry, are acidulated partly with this acid, partly with citric acid. It is present in hemlock, and in many other vegetables.

To obtain it pure, the juice of apples may be evaporated to dryness nearly, digested in alkohol, and the strained solution neutralized with chalk. Water will dissolve the malate of lime. The lime may be separated by the slow addition of sulphuric acid and gentle evaporation.

Or it may be obtained by macerating sheet-lead in fresh apple-juice; after a few days, crystals of malate of lead will be produced, which may be washed, and decomposed by sulphuric acid.

Malic acid is a colourless, syrupy, transparent, uncrystallizable, acid liquid; but it is difficult to obtain it pure and colourless.

It forms deliquescent salts with the alkalies, and crystallizable salts with most of the earths and metallic oxides. They have not been used.

Article 34. Mucic, or Saclactic Acid.

When gum is treated, in a gentle heat, with two parts of nitric acid, nitrous gas and carbonic acid escape, and as the mixture cools, a white powder falls down. Different gums,

according to Messrs. Fourcroy and Vauquelin, yield from 14 to 26 per cent. of this acid.

It is soluble in about 60 parts of cold water. It tastes sour, reddens litmus, and forms crystallizable salts, with oxides, which are readily soluble.

It is produced also, by treating sugar of milk with four parts of nitric acid.

It consists of, according to M. Gay-Lussac,		According to Berzelius,
Carbon . .	33.69	33.43
Hydrogen .	3.62	5.105
Oxygen . .	62.69	61.465

Article 35. Benzoic Acid.

This acid is procured from the resins or balsams, called balsam of Peru, benzoin, storax, tolu. It is obtained by powdering the substance with one-sixth of its weight of lime, and boiling the mixture in six times its weight of water, for half an hour, and filtering off the clear solution of benzoate of lime. Evaporate to one-half, and precipitate the solution of benzoate of lime by the gradual addition of muriatic acid. It may be sublimed by a gentle heat, and condensed in cones of tin or paper.

The benzoic acid thus prepared, is in white, very light brilliant, flexible crystals. It has a peculiar and agreeable smell, and rather a warm taste. It is soluble in twenty-four parts of boiling water, and in 20 times as much cold. The solution reddens litmus. It is soluble in alkohol, from which it crystallizes by spontaneous evaporation, into beautiful, large, transparent, thin crystals, which are flattened prisms.

It forms saline compounds with the earths, alkalies, and metallic oxides, most of which are crystallizable.

Benzoate of ammonia forms in feathery soluble crystals. It is used as a reagent for iron, which it renders apparent, by precipitating it of an orange colour, and insoluble.

The acetic acid also has frequently been met with native in vegetables. Its properties will be treated of after speaking of fermentation.

Several other acids have been described, as existing in small quantity, and in particular vegetables; such as the moroxylic in the bark of the white mulberry; the meconic found in opium; the boletic obtained from the boletus-pseudo-ignarius; the fungic from several of the fungous vegetables; the kinic from Peruvian bark; the ellagic, an unknown acid, lately obtained by M. Braconnot from galls; the zumic; the laccic, an acid described by Dr. Pearson as being to be found in stick lac; and the igasuric, obtained from the nux vomica. These acids, however, exist in very minute quantity, and are scarcely known except to the respective discoverers; and a few others.

Article 38. Other peculiar Principles.

Besides these principles, which are more or less general, a considerable number have been recently discovered in particular vegetables, and which appear to confer on them their peculiar properties. The number pointed out is daily increasing. Our limits will merely allow us to name some of them. These are cinchonia; quinine, the sulphate of which is now much used, as being the substance to which cinchonia or Peruvian bark owes its medicinal properties; emetin, produced from ipecacuanha; fungin; medullin; nicotin; olivine; asparagin; aconita; atropia, veratria; strychnia; picrotoxia; morphia, obtained from opium; hyoscyama; datura; delphia; cicuta, and some others; several of which form saline compounds with acids, and hence are named alkalies; while others form compounds with alkalies, and hence are considered as being acids.

Part 3.

Article 1. Fermentation and its Products.

While a vegetable is alive, its vital powers are in constant action, and its various parts and principles are perpetually undergoing changes, to adapt them to their final intentions. The mucilage of the young plant is gradually changed for starch, or gluten. The acid of the young fruit becomes sugar, to be again changed into another acid; and the sap of the vegetable is regularly converted into the requisite principles in a manner totally unknown to us.

When a vegetable loses its life, all these changes cease, and the different parts are now left to the actions of the general chemical agencies. By these they are frequently decomposed. These decompositions vary in rapidity, manner, appearances, and products, according to the nature of the agencies that are called into action.

A number of vegetable principles are not susceptible of any spontaneous change, that is apparent; others are susceptible of change when in certain mixtures only; and in all cases, a certain quantity of water and warmth are necessary.

When the spontaneous decompositions assume certain appearances, the name fermentation is given to them.

When a quantity of gluten of wheat flour, mixed with a very small proportion of water, is kept for a length of time, it is slowly and gradually converted into a sort of cheese, before the elements finally separate.

When the flour of wheat is mixed into a tolerably stiff paste with water, and kept in a moderately warm temperature, after a time, a fermentation or spontaneous change commences, but it proceeds very slowly; the gluten and the starch of which the wheat is composed gradually lose their properties; a quantity of carbonic, and shortly after

of acetic acid, is evolved; and if at this time the dough is baked, an ill-looking sour bread is produced.

When the new made paste is mixed with a small quantity of fermenting yeast, and kept in a warm temperature, the fermentation commences immediately and generally through the mass. The different substances that are present act rapidly upon each other. After a few hours, both the gluten and the starch are much altered; the mass is converted into dough, which, from the general evolution of carbonic acid gas, is rendered light, spongy, and porous. This change takes place so simultaneously, and so rapidly, that neither spirit nor acetic acid is formed. If the dough be now baked, good sweet bread is procured, in which neither gluten nor starch are to be found.

This is what is called panary fermentation.

Article 2. Vinous Fermentation.

The name of vinous fermentation is given to those processes in which this tendency to spontaneous decomposition is directed to the production of beer, alkohol, or wine.

For the production of these liquors sugar and gluten are necessary, a certain proportion of water and a moderately warm temperature. Other substances are generally present, such as starch, mucilage, gum, albumen, or vegetable acids: when present they are more or less decomposed, and consequently affect and modify the products.

The farinaceous seeds, from which beer is usually produced, are principally composed of starch, gluten, albumen, mucilage or gum, in varying proportions. Little sugar is present. Before the desired fermentation can be produced in them therefore, sugar must be added, or some process pursued by which it may be formed from the substances present. The process of malting produces this change.

The operation of malting depends upon a proper regulation

of the action produced by exciting the dormant vital power of the seed. The seed, barley for instance, is steeped in cool water until it is duly saturated, which is generally about a day and a half, and then the extra water is drawn off. The same changes commence in it as when it is planted for growth. It absorbs water, swells, the temperature rises a little, and the farina in the cotyledons undergoes the change ordained for supplying nourishment to the embryo plant; carbonic acid and sugar are produced. The radix and the plumula are at the same time evolved. To prevent the temperature from rising too high, the barley is spread out to a certain thickness, and frequently turned, and spread out thinner. At length the root appears, and the plumula, or acrospice, as the maltsters call it, extends within the coat or husk. When the plumula has attained a certain length, and before it penetrates the coat of the seed, it is known by experience that the evolution of the sugar has proceeded to its full extent. The vegetation is now stopped by drying the malt, as quickly as is convenient, in a stove. The vitality is thus destroyed, the roots become brittle, and are separated. The seed has become more bulky by two or three parts in the hundred, and has lost about one-fifth in weight. It has become softer and more brittle, and has acquired a peculiar sweet taste and smell, both of which are known as characteristic of malt.

The sugar thus produced differs from that of the cane. It does not appear to be crystallizable; it is more soluble and mucilaginous, or it is intimately mixed with a mucilage. It is readily decomposed by heat.

For the preparation of beer, the malt, previously crushed, is infused in as much water, not higher than 180°, as will cover it. After about three hours, this liquor is drawn off and more added, in proportions governed by the intention of the brewer.

If the first water be added at too high a temperature, the

starch and albuminous matter that may be present coagulate, and prevent the free passage of the water.

Generally speaking, the specific gravity of the liquid, to ferment favourably, should be between 1.02. and 1.14; that is, the vegetable matter should not be less than 8, nor exceed 58, per cent.

If this wort were left to itself, after the boiling with hops, and cooling, the fermentation would proceed very slowly and imperfectly; one part would pass into alkohol, and another into vinegar, before another part would suffer any change; yeast, therefore, a peculiar substance already in the state of fermentation, is added to the wort, and the temperature kept at 60° and 65°; fermentation, however, will go on more or less slowly, at any temperature between 50° and about 140°. The fermentation then soon commences, and spreads rapidly and simultaneously through the whole mass. A quantity of carbonic acid is progressively and slowly evolved, which keeps the liquor in constant internal effervescence, and for a time increases its volume. When the fermentation is sufficiently advanced, the beer falls or shrinks in volume again. It is then put into casks, placed in a cooler situation, and as soon as the evolution of carbonic acid, which has been going on during the fermentation, abates, the casks are partially, and at length finally, stopped.

There are many precautions necessary in practical brewing which cannot be dwelt on here, in order to regulate the strength, flavour, or peculiarities of the beer which it is intended to produce.

In the fermentation of corn for distillers' wash, the flavour of the liquid is not attended to. The object is to produce the largest possible quantity of brandy. A small proportion of malt is accordingly used with a large proportion of fresh corn; the expense of the malting is then in part saved. The maceration is carried on for a longer time, during

which time the sugar is evolved. A larger proportion of yeast is employed, the temperature is kept up, and the fermentation thus rendered more rapid and simultaneous; that the whole mass of sugar may, as far as is possible, be converted into alkohol at the same time. The liquor is then poured into stills, and the spirit distilled off. This spirit is sold under the name of malt spirit, or common British brandy. By re-distillation it is deprived of the greater part of the water and flavour, and is then known in common by the name of rectified spirit.

In France, brandies are drawn from such fermented wines as are unfit for sale. The rums of the West Indies are products of the fermentation of refuse saccharine matter.

The fiscal regulations under which the distillers in Scotland were placed not long since, produced a singularly ingenious contri[illegible]nce. The tax was levied according to the size of the still, from a supposition that the quantity of spirits drawn by a still would be proportionate to its size. A still was in consequence shortly contrived, holding about 40 gallons. It was constructed very low and flat, with free charging, and discharging apertures. It was usually charged with 16 gallons of wash, and is said to have been worked the unparalleled number of 480 times in 24 hours. There is a plan of this still in Ure's Dictionary.

When the juice of ripe grapes, currants, plums, gooseberries, or cherries, particularly of the former, is pressed out, it immediately goes into fermentation. The must from these fruits contains sugar, gluten, mucilage, and vegetable acids. The juice of grapes is generally better flavoured, and is rich enough to produce wine without addition. The juice of the other fruits requires a large addition of sugar; and the sugar that is employed being in the state of raw or refined sugar, makes a considerable difference in the flavour and properties of the wine.

Fermentation in this must commence spontaneously

without the addition of yeast or ferment, on its temperature being elevated to between 65° and 80°, and continues more slowly, and regularly, and for a longer time, than in the former cases. When rich in sugar, the disposition to pass on to the acetous fermentation is not so great, so that there is time for the more complete decomposition of the sugar, and other principles, and for their conversion into vinous liquor. The vegetable acids appear to become in part decomposed, and considerably to modify the fermentation, and the product.

It is of great consequence to the perfection of wine, that the fermentation be stopped in proper time, and the vessels closed from the action of the air. A slow internal imperceptible action then continues, which completes the properties of the wine.

During the fermentation of all these liquors, a quantity of thick frothy scum is thrown up to the surface, which is called the yeast. The peculiar valuable property of this yeast, of exciting or increasing fermentation in fermentable substances, has attracted a good deal of attention. A quantity of beer yeast which was examined by M. Westrumb, contained, besides vegetable acids and alkohol, a quantity of mucilage, sugar, and a sort of gluten. The gluten, the elements of which are in a state of loose combination, appears to be the principal necessary ingredient. When removed by straining, the fermenting property ceases, when added again, the power of producing fermentation is restored.

In whichever of these modes the fermentation is carried on, the alkohol produced by distillation is the same.

In brewing particular kinds of beer, the chief object of the brewer is to obtain a particular flavour and appearance. The alkohol is modified and united during the fermentation with the undecomposed saccharine and mucilaginous matter, and further flavoured by the hops, and, in porter, with

a portion of acetic acid; but the proportion of alkohol is comparatively small.

Generally the fermentation is carried on in the open air; but this is not necessary, and there is a considerable waste of alkohol and of flavour, which would be saved by fermenting both beers and wines in close vessels, connected with a simple apparatus, in which the alcholic vapour may be condensed, and the uncondensable gasses alone suffered to escape.

Article 3. Alkohol.

To obtain alkohol pure, the rectified spirit of commerce, the specific gravity of which is usually .835 at 60°, may be distilled in a glass retort with a fourth of its weight of carbonate of potassa, fresh dried and yet warm, and drawing over about three-fourths of the spirit. The specific gravity of this spirit is usually .817 nearly. If the process be repeated, the specific gravity will be reduced to .810, or perhaps lower. It is said to be reduced by subsequent rectification from muriate of lime, previously dried at a bright red heat, to .791. It is probable that in this case a partial decomposition is produced, and some ether formed.

Pure alkohol is extremely limpid, has a fragrant penetrating smell, and a warm pungent taste. It boils at 176°, under the pressure of the atmosphere; and in a vacuum at 56°, or lower. It evaporates rapidly when exposed to the air. It was exposed to —91 without congealing. But Mr. Hutton gives an account of alkohol, specific gravity .798, having been frozen by a cold equal to —110°; but how such a degree of cold was produced, or how the temperature was ascertained, he does not say. M. Bussy froze alkohol of .837 with the cold produced by the evaporation of liquefied sulphurous acid.

The specific gravity of the vapour of alkohol is 1.6, compared to air.

Alkohol may be mixed with water in any proportion. The mixture suffers a small condensation in volume, varying with the proportions of the ingredients.

The alkohol in brandy, rum, whisky, and all other spirits, is the same in its properties, and varies only in flavour.

In consequence of its extensive consumption, and the fiscal charges it is subjected to, very extensive and accurate tables have been formed, the results of numerous experiments, to point out the proportion of alkohol in different liquors by their specific gravity. The tables adopted by the British government were prepared by its direction, under the inspection of the Royal Society, and are voluminous. Various abbreviations of them are published, and the hydrometer employed by the officers of government is founded upon them.

In these tables 825° is considered as the specific gravity of pure alkohol.

Table of the specific gravities of mixtures by weight of 100 parts of alkohol with different proportions of water; and of the amount of their respective condensations in volume; at 60°.

Parts by Weight of Water.	Sp. Gravity.	Condensation in Volume.
0	.82500	0.
5	.83599	0.5
10	.84568	0.94
15	.85430	1.32
20	.86208	1.66
25	.86918	1.98
30	.87569	2.27
35	.88169	2.55
40	.88720	2.81
45	.89232	3.06

Parts by Weight of Water.	Sp. Gravity.	Condensation in Volume.
50	.89707	3.30
55	.90144	3.52
60	.90549	3.72
65	.90927	3.91
70	.91287	4.11
75	.91622	4.29 proof sp.
80	.91933	4.47
85	.92225	4.63
90	.92499	4.79
95	.92758	4.94

Table of the specific gravity of mixtures by weight of 100 parts of water with different proportions of alkohol, and the amount of the respective condensations in volume.

Weight of Alkohol.	Sp. Gravity.	Condensation.
100	.93002	5.09
95	.93247	5.23
90	.93493	5.38
85	.93749	5.53
80	.94018	5.68
75	.94296	5.85
70	.94579	6.02
65	.94876	6.18
60	.95181	6.36
55	.95493	6.53
50	.95804	6.66
45	.96122	6.78
40	.96437	6.83
35	.96752	6.81
30	.97074	6.72
25	.97410	6.59

Weight of Alkohol.	Sp. Gravity.	Condensation.
20	.97771	6.21
15	.98176	5.75
10	.98654	5.13
5	.99244	4.30

By proof spirit is meant a mixture of alkohol and water, in such proportions as produces a specific gravity of nearly .916 at 60°. It consists, by weight, according to the tables above-mentioned, of

Spirit, of the specific gravity .825 at 60°, 100 parts.
Water . . . . . 75 parts.

It is the *supposed* strength of brandies, and the strength on which the government duties are levied.

Alkohol is readily inflamed. It produces a pale blue flame, and burns away without smoke and without leaving any residuum. But if passed through a red-hot copper tube, carbon is deposited, and carburetted hydrogen evolved.

The colour of its flame may be varied by the addition of various substances. Nitre gives it a yellow tint, nitrate of baryta the same, nitrate of strontia produces a beautiful red, nitrate of copper a green, and boracic acid a yellowish green.

The expansion of alkohol by heat is very considerable, and its proportionate expansion increases with the temperature.

It dissolves sulphur, phosphorus, the pure alkalies, a considerable number of neutral salts, soap, many of the vegetable principles, most volatile oils, and resins. Most of the substances which are not soluble in water also, are precipitated from alkohol, by its superior attraction for water.

According to the ultimate analysis of Dr. Ure, alkohol of the specific gravity of 812°, is constituted of carbon

47.85, or 3 atoms 18; hydrogen 12.24, or 5 atoms 5; oxygen 39.91, or 2 atoms 16.

When brandy, or diluted alkohol, is kept in a wide-mouthed or cylindrical vessel, covered closely with a bladder, the water slowly escapes, leaving the alkohol, which consequently becomes concentrated. This takes place, even when the bladder is covered with lead, and the juncture pointed. It is said that alkohol may be rendered perfectly pure, by keeping it for a short time in ox bladders, and in a warm temperature.

In wines, the proportion of alkohol is much larger than in malt liquor, and it is so intimately combined with the other ingredients, that it cannot be separated completely by distillation, without a previous chemical process.

This process was first pointed out by Mr. Brande. A solution of acetate, or subacetate of lead, is poured into the wine to be examined; a dense insoluble precipitate falls down, and may be separated by filtration. On adding to the clear liquor, warm, dry subcarbonate of potassa, it absorbs the water, and any acid that may be present, and leaves the alkohol nearly pure.

From a number of experiments on different wines, Mr. Brande produced the following table, shewing the proportion of spirit, per cent. by measure, in 100 parts of different wines and spirituous liquors. Many of these results are the average of several experiments.

1. Lissa	25.41	9. Colares	19.75
2. Raisin	25.12	10. Lachryma Christi	19.70
3. Marsala	25.09	11. Constantia, white	19.75
4. Port	22.96	12. Constantia, red	18.92
5. Madeira	22.27	13. Lisbon	18.94
6. Currant	20.55	14. Malaga	18.94
7. Sherry	19.17	15. Bucellas	18.49
8. Teneriffe	19.79	16. Red Madeira	20.35

17. Cape Muschat	18.25	38. Champagne .	12.61
18. Cape Madeira .	20.51	39. Red Hermitage .	12.32
19. Grape Wine .	18.11	40. Vin de Grave .	13.37
20. Calcavella . .	18.65	41. Frontignac . .	12.79
21. Vidonia . . .	19.25	42. Cote Rotie .	12.32
22. Alba Flora . .	17.26	43. Gooseberry Wine	11.84
23. Malaga . . .	17.26	44. Orange Wine .	11.26
24. White Hermitage	17.43	45. Tokay . . .	9.88
25. Rousillon . .	18.13	46. Elder . . .	8.79
26. Claret . . .	15.10	47. Cider	7.04
27. Zante . . .	17.05	48. Perry . . .	7.26
28. Malmsey Madeira	16.40	49. Mead . . .	7.32
29. Lunel . . .	15.52	50. Ale	6.87
30. Shernaz . .	15.52	51. Brown Stout .	6.80
31. Syracuse . .	15.28	52. London Porter	4.20
32. Sauterne . .	14.22	53. Ditto Small Beer	1.28
33. Burgundy . .	14.57	54. Brandy . . .	53.39
34. Hock . . .	12.08	55. Rum	53.68
35. Nice	14.63	56. Gin	51.60
36. Barzac . . .	13.86	57. Scotch Whiskey	54.32
37. Tent	13.30	58. Irish Ditto . .	53.90

When the intention of fermentation is merely to produce the largest quantity of alkohol, as is the case with the distiller, the quantity of alkohol produced appears from the experiments of Messrs. Saussure, Thenard, and Dr. Thomson, to be at least equal to half the weight of the soluble matter of the malt or sugar that is decomposed.

Article 4. Ether.

Alkohol is acted upon by concentrated acids, and a class of bodies called ethers produced. Pure ether, or as it is called, sulphuric ether, is prepared by slowly mixing, in a cool temperature, equal weights of alkohol and of concen-

trated sulphuric acid, in a capacious glass retort, adapting a receiver; then applying heat, which is to be raised so as to make the liquid boil as quickly as is convenient: the receiver should be kept cool by cold water. A light fragrant liquid comes over, which may be purified by mixing it with lime, or dry carbonate of potassa; and then redistilling off about three-fourths of the first quantity. Ether is a remarkably limpid volatile fluid. It is so extremely inflammable, and so is its vapour, that it is not safe to approach it to a fire or a candle. A little of it enclosed in a bladder may readily be converted into vapour by warm water, or the warmth of a fire; and then it burns like an inflammable gas as it issues from the pipe. If its vapour be mixed with oxygen, an explosive mixture is produced.

The general specific gravity of good ether is about .730. It may, by further rectification, be obtained at .700, and according to M. Lowitz, at .632. It has a fragrant penetrating, peculiar smell, and a pungent taste. Under atmospheric pressure it boils at about 98°; but its boiling point varies with its purity, and is rendered unsteady by various contingent circumstances to a greater extent than most other fluids: connected apparently with the comparatively small difference there is in the respective capacities of liquid ether, and its vapour.* According to Dr. Bostock,

* In some experiments made by the writer's son, during last autumn, it was observed, that the boiling temperature of the same liquid, varied with the conducting power of the vessels; and, perhaps, with the cohesive attraction between the vessels and the liquid. It appeared to be affected also, by the depth and degree of exposure of the liquid, and by the roughness or smoothness of the surfaces. When water, or a solution of sulphuric acid and water in a glass vessel, that was placed in a sand heat, and had just ceased to boil, was touched with a glass rod, the ebullition returned; and became more rapid as the rod was sunk in the liquid. When the sand heat was heated most on one side, the ebullition became more rapid as the rod approached that side; when a rod of wood was introduced, the ebullition was still more rapid; when a bit of paper was introduced, whether in water or in ether, the ebulli-

(Ann. Phil. for March,) ether, of the specific gravity of .755, boiled in one vessel at 112°, in another at nearly 150° and 175°. In a vacuum, ether boils at 52° below the freezing point of water. Consequently at that temperature, it would be a permanent gas, were the pressure of the atmosphere removed. Exposed to the air, it volatilizes with great rapidity. When dropped slowly from the mouth of a vial, the drops evaporate in their passage towards the ground. During the evaporation, an extreme degree of cold is produced. It becomes solid at 46° below 0°; that is, at 78° below the temperature at which water freezes.

It dissolves about one-tenth of its weight of water. Water, on the other hand, dissolves a small proportion of ether.

It dissolves sulphur in a small proportion, and phosphorus. It dissolves the oxides of gold and platinum, separating them from their nitro-muriatic solutions, and as it evaporates, depositing them in a metallic state.

It dissolves a number of vegetable bodies, and is in consequence frequently used as an agent in vegetable analysis.

Ether, of the specific gravity of .7, appears to consist of carbon 59.6, or three atoms 18, hydrogen 13.3, or 4 atoms 4, + oxygen 27.1, or 1 atom 8; = 30.

Pure ether, it seems, may be obtained by acting upon alkohol with phosphoric or arsenic acids.

A number of ethers may be prepared also by the action of nitric, muriatic, acetic, hydriodic, oxalic, tartaric, citric, benzoic, and gallic acids.

These ethers are more complicated, all of them containing a portion of the acid in their composition.

tion was further increased; and still further, when the surface was sprinkled with an earthy dust. In these cases, as the ebullition increases, the rate of evaporation also increases. When the surface is broad, and the caloric applied chiefly to the upper part of a liquid, the rate of evaporation may, as has been remarked, be rapidly increased without any ebullition.

The drug known by the name of sweet spirit of nitre, is nitric ether diluted with alkohol.

The four first ethers are formed by the direct action of the acids on alkohol. The remainder require the intervention of a mineral acid to produce the combination. They are, most of them, very volatile, and produce a considerable cold during their evaporation.

Article 5. Acetous Fermentation.

§ 1. When the fermentations in the cases just described are permitted to continue uninterrupted, the temperature raised to 70° or 80°, and a free access of oxygen admitted; in a few weeks the whole of the saccharine matter, and of the new-formed alkohol disappear, and are replaced by acetic acid.

In the manufacture of vinegar, the liquor to be fermented is generally made weaker than the liquors prepared for vinous fermentation; and the fermentation is carried on from the first, at a higher temperature, and in open vessels. The evolution of alkohol is, in consequence, scarcely noticed.

§ 2. *Common Vinegar* is *Acetic Acid* diluted with a quantity of water, and disguised by mucilage and other vegetable matters; from the two latter it may be freed by distillation.

Acetic acid is obtained by the distillation of wood also at a red heat. Several manufactories are now established in different parts of England for obtaining it in this manner.

Cast-iron cylindrical retorts, three or four feet in diameter, and about six feet long, are set in pairs; somewhat in the manner of coal gas retorts, each holding from six to eight hundred weight of wood. The woods employed are ash, birch, oak, and beech, woods that are free from resin. The retorts are heated to a red heat, and kept so for ten or twelve hours, during which time the wood is converted into a perfect charcoal, which weighs about one-fifth of the

wood employed; and from two to three hundred pounds of acid liquor is obtained, strongly impregnated with a dark fetid oil, or tar. Besides which, a large quantity of carburetted hydrogen is produced. The acid, after being strained, is saturated with lime, lightly roasted, decomposed by sulphuric acid, and distilled. If it is not perfectly sweet, this process may be repeated; when a pure, colourless acid is produced, of such a strength as to require dilution with eight or twelve proportions of water to adapt it to domestic use.

A still stronger acetic acid may be obtained by the distillation of dry acetate of lead, or of potassa with concentrated sulphuric acid, or with dried sulphate of iron; or by the distillation of verdigris, or subacetate of copper by itself. This acid has a powerful pungent smell; and when impregnated with an essential oil, is the aromatic vinegar so well known.

The acetic acid, when pure and concentrated, has a pungent fragrant smell. When at its greatest strength, its specific gravity is 1.062. This acid crystallizes at 50°.

It is constituted of,

According to Gay-Lussac and Thenard,		According to Berzelius,	
Carbon	50.22		46.83
Hydrogen	5.63		6.35
Oxygen	44.15		46.82

The latter analysis would represent it to be composed of carbon 4 atoms 24, hydrogen 3 atoms 3, + oxygen 3 atoms 24; = 51.

It combines with the alkalies, earths, and oxides, forming regular saline compounds; which, generally speaking, are soluble, deliquescent, and not easily crystallized.

§ 3. Acetate of ammonia, the solution of which is Mindererus spirit, is a soluble, nearly tasteless salt.

§ 4. Acetate of potassa has been long used in medicine,

under the name of diuretic salt. It may be evaporated to dryness and fused, when it breaks into white, opaque, shining, longitudinal, lamellar, crystals, having a saline, slightly sharp taste, and being soluble in their weight of water.

§ 5. Acetate of lime is formed, for the convenience of purifying the acid when distilled from wood. It is employed by calico-printers, also, in the decomposition of alum, to supply them with acetate of alumina; which they frequently use as a mordant.

§ 6. Acetate of iron is used by calico-printers only. They obtain it by digesting iron in the wood acid, or else, by decomposing acetate of lead with sulphate of iron. It produces green soluble crystals, having a styptic taste.

§ 7. Acetic acid, by combining with copper, produces verdigris. The common verdigris is a subacetate, and is insoluble in water. The neutral acetate, called in commerce distilled or French verdigris, forms beautiful green crystals, soluble in twenty parts of water at 60°. Acetic acid seems to form several other compounds with the oxides of copper.

§ 8. Acetic acid combines with lead in two proportions.

The acetate of lead is formed by dissolving carbonate of lead in the acid. When fresh, it is in small prismatic white shining crystals. By keeping and exposure to air, they lose their brilliancy, and become yellowish.

This salt has an astringent sweet taste, and is soluble in four parts of water at 60°, generally throwing down a small portion of insoluble carbonate.

Acetate of lead is used extensively by calico-printers, in the preparation of their acetates of alumina and iron. It is used also by painters, to promote the drying of their oils.

Subacetate of lead, or Goulard's extract, is prepared by boiling the yellow oxide of lead, or litharge, in vinegar, and decanting the clear liquor. It may be prepared by boiling

in water 100 parts of acetate of lead, with 150 of the yellow oxide. It is difficult to crystallize. It is chiefly used in medicine.

The acetate of mercury is sometimes used in medicine.

§ 9. The acetate of silver, which is in small acicular crystals, is used as a test for muriatic acid. Some other acetates are used as tests also.

The numerous and various uses of acetic acid, are in general well known.

M. Turrel has lately recommended the following mixture for etching upon steel: four parts, by measure, of the strongest pyroligneous acid, one part of alkohol. When they are well mixed, add one part of pure nitric acid. Its action may, if necessary, be quickened by adding more nitric acid.

Section III. Of Animal Compounds.

Part 1. *General Properties.*

Animals, like vegetables, surround us in almost infinite numbers and varieties, constituting an almost regular gradation. Each animal, too, consists of a great diversity of parts. The substance of different animals, and of their respective parts, is made up of various peculiar animal compounds, which are adapted by the Creator to their respective uses. These constituent compounds are called animal principles.

Like the vegetable principles, they are constituted of very few elementary bodies. They consist chiefly of carbon, hydrogen, oxygen, and nitrogen; in most cases with minute proportions of various other bodies, the principal of which are sulphur, phosphorus, and their acids, muriatic acid, potassa, soda, lime, magnesia, silica, iron, and manganese, more or less compounded.

The animal principles pretty uniformly contain a large proportion of nitrogen, which gives them a peculiar general character; and they are, generally speaking, more complicated combinations than the vegetable principles. In consequence of which, they have generally a stronger tendency to spontaneous decomposition, and the productions of the consequent play of chemical attractions is very different.

The productions of decaying animals are much more offensive, and evolve a large proportion of ammonia, so combined as to produce very offensive odours.

When distilled at a red heat, in close vessels, they are decomposed. A large quantity of ammonia is produced, carbonic acid, water, and a quantity of very offensive black oil, commonly called oil of hartshorn, attend it; and a dense hard black charcoal, varying according as the body distilled contains carbonate or phosphate of lime, or any other unvolatizable body, remains in the retort. Benzoic, acetic, hydrocyanic acids, cyanogen, and several gasses, are frequent productions also.

In what manner these principles are produced from their elements, we know no more than how vegetable principles are produced. The powers of life in animals are more active than in vegetables, and exert a more extensive agency over chemical attraction; which indeed it may be said to govern, and guide to its own purposes, rather than suspend; for we see the chemical agencies are always permitted to act, when their actions tend to promote a final intention. In the stomach, for instance, the vital powers influence the actions going on in the glands of the stomach, so as to produce a secretion, having the peculiar chemical properties that are required to enable it to convert the various food that may pass into the stomach, into a peculiar compound called chyme. When poured into the stomach, it is left to exert its chemical agency; so that digestion appears to be

a mere chemical process, preparing the food in a peculiar manner previously to its being converted into living matter.

The ovum, or egg, of the animal corresponds to the seed of the vegetable. But the structure is more complicated, and the vitality more liable to be destroyed. Like the vegetable seed, the egg consists of a minute embryo, so small that its structure cannot be traced; but from which the infant animal is hereafter evolved. This embryo is connected with the yolk and the albumen, so that they may be absorbed and converted into nourishment as it is required, by the evolution of the animal.

Until the period of incubation, the vital power seems dormant, as in vegetable seeds; but its existence is apparent from its preserving the liquid, yolk, and albumen, from the influence of those chemical attractions which would otherwise inevitably decompose them; and from its capability of being excited into action by the application of a proper stimulus. On the continued application of a temperature of about 100°, whether from the body of the dam, or from a stove, the vital powers are stimulated into action, and the vessels of the embryo enlarge and extend. In the more perfect animals, the brain and heart are first perceptible, and the other parts are successively evolved. During this time, the yolk and albumen are absorbed by proper organs, and assimilated, in a manner unknown to us, to the principles that are necessary for the construction of the respective organs; and to fit it for hereafter seeking its own support.

As animals, generally, are intended to have perceptions, and the power of locomotion, they do not draw in nourishment by roots, but are furnished with a hollow bag, into which the nourishment they occasionally take passes, and where it is digested and assimilated. The substances of

principles it is converted into, vary according to the final cause, as it is called; that is, according to the wants or uses of the animal, and of its respective organs.

The more general animal substances, therefore, are extremely various, but the variations are sometimes so gradual and indistinct, that it is by no means easy to class them under general heads. Frequently those that appear to possess marked distinctions, are intimately connected by an intermediate chain of resemblances. At other times they are so intimately mixed, as to disguise each other; and sometimes they are disguised by the action of the agents necessarily employed to separate them.

As they cannot all be individually described, such of them as are best known shall be spoken of under a few general heads.

Part 2. *Animal Principles.*

The most general of the animal principles, those of which, in combination with more or less water, the different parts of animals are chiefly composed, may be described under the articles,

1. Gelatine
2. Albumen
3. Fibrin
4. Mucus
5. Fats
6. Blood
7. Muscle
8. Skin
9. Membranes, tendons, ligaments
10. Bones
11. Brain
12. Horn, nails, hair, feathers
13. Chyme
14. Bile and picromel
15. Chyle
16. Milk
17. Ear-wax, and other secretions
18. Urine
19. Urinary calculi
20. Other concretions and secretions.

Article 1. Of Gelatine.

This principle may be obtained abundantly from many parts of most animals, and is generally more abundant in young animals, and more scarce in old.

It would appear to be the most readily produced, and the first product of animalization. As the parts of animals are first evolved in the fœtus, they appear to be composed almost wholly of gelatine; and at the period of birth contain a large proportion of soft gelatine in the bones, muscles, and all other parts. As the age advances, the textures harden, and the gelatine becomes firmer; its proportion too gradually diminishes: and at length, in old animals, cannot be obtained at all from some parts; from muscle, for instance, from cartilage, and from bone.

It is obtained most abundantly from the skins of animals. It appears to constitute a part of the membranes, tendons, ligaments, and even cartilages, of young subjects, as well as hoofs and horns. It may be obtained from these parts simply by boiling them in water, and straining off the liquor. M. Berzelius, however, denies the existence of this supposed principle in the living animal, and asserts that it is produced by the process of boiling. It does not exist ready formed in the blood. When an animal solid, which is supposed to contain gelatine, a piece of skin, for instance, is macerated in cold water, no gelatine is obtained. When the maceration is long continued, and putrefaction appears to be approaching, the whole mass becomes thickened, soft, of a gelatinous feel, although no gelatine separates. But when the skin is boiled for a length of time, it contracts, thickens, and gradually hardens, giving out gelatine slowly, but the more readily the younger the animal. The skins of young animals thus readily boil almost wholly into gelatine; while those of the older require much

longer boiling; and retain to the last a considerable portion of hardened albumen; and some bodies give out very little gelatine, unless boiled under such pressure as shall raise the temperature of the water considerably.

It is probable, therefore, that gelatine, when it exists in animals as such, is chemically combined with the other proximate elements, so that a certain attractive force must be overcome to obtain it.

When pure and dry it is a colourless, transparent, hard, horny substance, which, while dry, is unalterable by air or time, and is more or less readily softened by maceration in cold water. When dissolved in water, it produces that peculiar elastic tremulous body termed jelly. Glue, portable soup, and isinglass, are rather impure specimens of gelatine in its dry state. The solution continues liquid while warm, u l unless the quantity of water be too large, it becomes solid and tremulous on cooling. According to the experiments of Dr. Bostock, one part of isinglass is sufficient to gelatinize 100 parts of water. This solution, after a few days, the sooner in proportion to the warmth of the temperature, becomes sour, and at length putrefies. It is decomposed by concentrated acids. Treated with sulphuric acid, as M. Braconnot pointed out, it may be converted into a sort of sugar.

The gelatine of young animals is more readily dissolved in water than that of old, producing a weaker and less adhesive jelly, that cannot be formed into a strong glue. On the other hand, the skins of old animals, the tough hides of the ox, and of other large animals, require long boiling to obtain the gelatine: when obtained, however, it forms a very strong, hard, adhesive glue. The hide of the rhinoceros is said to require very long boiling, and to produce uncommonly hard strong glue.

Dead animal matter, when very young, in consequence apparently of the large proportion of w ak gelatine, have a

strong tendency to acetous fermentation, in the commencement of its spontaneous decomposition; demonstrated by the acid smell which precedes putrefaction.

Gelatine is soluble in solutions of potassa and soda; from which it is not separated by the subsequent addition of an acid. It is soluble in acids. It precipitates the oxides of some metallic salts. It does not precipitate the subacetate or Goulard's preparation of lead, nor corrosive sublimate. It is not soluble in alkohol.

It precipitates with tannin into a firm insoluble durable compound, which dries into a hard brittle substance, that is not soluble in water, nor capable of putrefaction.

These two bodies are delicate tests of each other. A solution, containing a 5000th part only of gelatine, will produce a visible precipitate with infusion of galls. As the precipitate of gelatine and tannin appears to be a definite compound, tan is proposed as an analytical agent, to ascertain the quantity of gelatine that may be in any fluid. Dr. Bostock assigns the proportions in the precipitate to be nearly two parts of tannin to three of gelatine; but albumen also is precipitated by the same agent. Besides, different specimens of gelatine vary much in strength and firmness, and, doubtless, in the proportion of tannin they combine with.

According to the analysis of Messrs. Gay-Lussac and Thenard, dry gelatine is constituted of carbon 47.881, or 15 atoms; oxygen 27.207, or 6 atoms; hydrogen 7.914, or 14 atoms; nitrogen 16.988, or 2 atoms.

Article 2. Of Albumen.

This principle appears to be still more abundant even than the last, in the bodies, at least, of red-blooded animals. It is present in the blood, the skins, and other membranes. It exists, in considerable proportion, in the

ligaments, cartilages, horns, hoofs, and bones; and the hair, nails, claws, and feathers of animals, seem to be composed of hardened and modified albumen.

The white of an egg is esteemed as tolerably pure albumen, in combination with water, containing a portion of soda and of sulphur. It is a transparent, thick, glary, adhesive fluid, which may be mixed with water at a low temperature; or may be slowly dried into a brittle transparent substance, that is again soluble in water. But its peculiar and most remarkable distinguishing property is, that when exposed to a temperature of 160°, it becomes coagulated into an opaque white solid elastic substance, which is no longer soluble in water. When white of egg is coagulated, and gently dried, it loses about eighty-six per cent. of water, the greater part of which it is capable of reabsorbing; at the same time it gives out one-twentieth of a viscid fluid, which is not coagulable, but which precipitates subacetate of lead. This coagulation does not appear to be connected with any change in its chemical properties, nor is it connected with its previous vitality. Coagulated albumen is little affected by boiling in water.

Albumen is coagulated by acids, by alum, by alkohol, and by the gastric fluid of animals. It is dissolved in solutions of the alkalies, from which it is precipitated unchanged by acids. When white of egg is diluted with one hundred parts of water, it is rendered opaque and flocculent by a drop or two of corrosive sublimate; it is a still more delicate test if heat also be employed. An infusion of galls precipitates albumen. On pouring an infusion of galls into a solution containing one part of albumen in one hundred of water, a precipitate at length appears.

Coagulated albumen is a long time in becoming putrid; but when not coagulated, it putrefies more readily.

Mr. Brande has shewn that galvanic electricity is a most delicate test of the presence of albumen in animal fluids.

Many theories and fancies have been proposed to account for the coagulation of albumen, all of which are equally futile.

Its ultimate analysis shews that its constitution is not very different from gelatine, if the sulphur and soda, which appear to be ever present in it, are not constituent parts of it. It does not appear to evolve acetous acid during its spontaneous decomposition.

According to the analysis of Messrs. Gay-Lussac and Thenard, it appears to consist of carbon 52.883, oxygen 23.872, hydrogen 7.540, nitrogen 15.705.

Article 3. Fibrine.

Fibrine, or animal gluten, is an abundant principle in the blood of animals. The muscles are said to be principally formed of it. Its properties, however, are not satisfactorily defined. In cases of simple fracture of bones, or of incision through fleshy parts which are immediately replaced in contact, it is this part of the blood which, by its coagulation, constitutes the bond of union in the first place, the more fluid part of the blood being removed by the adjoining absorbents.

It is probably present, therefore, but modified and mixed with albumen in the muscles, membranes, tendons, ligaments, cartilages and bones of animals. It coagulates shortly after it is drawn from a living animal.

When a portion of fresh drawn blood is agitated for some time with a stick or whisk, a firm coagulum forms around it, which may be washed and macerated until the coloured part is removed. A yellowish white tough fibrous substance is left; this is fibrine combined with water.

The cause of the sudden coagulation of fibrine as soon as it is poured forth from the blood vessels, is not known. The late Mr. John Hunter considered it as a property com-

nected with its vitality, and impressed upon it, to fit it for its final uses. He observed, that in certain cases of instantaneous death, the fibrine does not coagulate, neither does it appear that the cause of death in these cases produces any chemical change in it; whence he inferred, that its coagulation is a property dependent upon its vitality.

When a piece of lean meat is drawn into shreds and macerated with cold water, which is changed daily for several days, and then boiled in two or three successive waters, it is considered by some chemists as another specimen of fibrine.

The fibrine of the blood is a tough elastic substance, much resembling the gluten of good wheat. According to Mr. Chevreul, 100 parts lose about 79 or 80 parts in drying. Boiled fibrine becomes brittle and semi-transparent when perfectly dry. In this state it keeps unchanged. When damp or soaked in water, it does not putrefy, but merely acquires an unpleasant smell.

It is insoluble in cold water. When boiled rapidly for some hours, it contracts, hardens, and renders the water opaline. Infusion of galls dropped into the liquor in which fibrine has been boiled, produces a loose brown flocculent precipitate. This liquor does not gelatinize when evaporated, but leaves a white friable substance, which is readily re-dissolved, and tastes similar to broth.

According to M. Berzelius, alkohol of the specific gravity of .810 decomposes fibrine, producing an adipocire, which is soluble in the alkohol, and precipitated by water. Ether has a similar effect. Concentrated acetic acid dissolves fibrine which has not been boiled; and with the addition of heat converts it into a tremulous jelly, that is soluble in warm water, but evolves a little nitrogen. By evaporation, a dry transparent mass is produced, which is not soluble without the addition of fresh acetic acid.

Braconnot, by treating the muscular fibre of beef with

sulphuric acid, obtained a new substance which he called leucine. It appears in small mamillated dull white crystals, lighter than water.

The ultimate analysis of fibrine, according to the experiment of Messrs. Gay-Lussac and Thenard, is: carbon 53.365 or 18 atoms, oxygen 19.685 or 5 atoms, hydrogen 7.021 or 4 atoms, nitrogen 19.934 or 3 atoms. It contains a larger proportion of nitrogen than gelatine and albumen, also to which it is nearly allied.

Article 4. Mucus.

Chemists are not agreed upon the existence of this substance as a distinct animal principle. This discrepancy of opinion arises out of the indefinite nature of all these principles as they occur in different animals. Frequently they are mixed; their properties in many cases approach each other, in others they deviate. The saliva of the human mouth is, however, a well known fluid. A very similar fluid is met with in different parts of various animals. To these fluids Dr. Bostock has endeavoured to restrict the term mucus.

When the saliva is evaporated to a solid state, re-dissolved in water, and filtered; or when oysters are macerated in water, and the solution treated in the same manner, specimens of mucus are obtained, which are more or less impregnated with saline bodies, from which it is very difficult to separate them.

Mucus, when dried, has much the appearance of gum arabic, but is more opaque. It is soluble in water, forming an adhesive solution with little taste, but it does not gelatinize. It is not soluble in alkohol, nor in ether. It does not coagulate when heated, nor is it precipitated by corrosive sublimate, nor by infusion of galls. But subacetate of lead produces a copious precipitate when dropped into it.

When exposed to a strong heat, it assumes a horny appearance, and as the heat is raised it is decomposed.

Article 5. Fat.

The animal fats and oils are a distinct, well marked class of bodies, which closely resemble vegetable expressed oils, generally speaking. They are met with deposited in distinct cells that are situated in different parts of animals, and are of different consistencies, colours, and flavours. When fluid at the atmospheric temperature, they are called oils; so that suet, lard, and oil, may be considered as varying chiefly in the temperature at which they become fluid.

Fats differ very much, according to their purity. They are generally more or less mixed with a quantity of mucilaginous and albuminous matter, peculiar to the animal they are obtained from; but when purified, as far as possible, the fats of different animals have each in general some peculiar properties to distinguish them.

When heated above 400°, they begin to emit a pungent vapour, and as the temperature rises to 600° and upwards, they become more readily decomposed, and the vapours that escape become more offensive. The products are nearly the same as from vegetable oils, when distilled at a high temperature; a very pure carburetted hydrogen is produced, a little ammonia, and some charcoal.

Fats are insoluble in water, cold alkohol, or ether. They combine with the alkalies, forming valuable soaps. The concentrated acids decompose them.

When long exposed to the air, and to a warm temperature, they are liable to a partial decomposition, and to become rancid, apparently from the action of the mucilaginous matter which is intimately mixed with them, and partly, perhaps, from the action of the oxygen upon them. But

oxygen is an agent which is always ready to explain what is not understood.

From the experiments of M. Chevreuil, it appears that animal fats, like the vegetable, consist of a variable mixture of the two substances before spoken of, elaine and stearine.

The stearine, or hard fat, may be obtained from a solution of lard in hot alkohol; as it cools, it separates in the state of white crystalline needles. Its melting point varies from 109° to 100°. It is brittle, tasteless, and inodorous, resembling wax in appearance.

The elaine, or oil, may be obtained by distilling off the remaining alkohol. It is fluid at 59° or lower. Frequently it has colour and smell.

M. Braconnot, who has also made many experiments on this subject, separates these bodies by means of bibulous paper, which absorbs the elaine only, and gives it out again when soaked in water and pressed.

Both these substances form soaps with alkalies, as before observed.

Train oil being obtained in great abundance, at a low price, and being at the same time very offensive, and loaded with the peculiar mucilaginous matter of the fish, various attempts have been made to purify it as an article of commerce. One mode of rendering it purer would be, to prepare it at a less elevated temperature, and keep the different strainings separate.

By being mixed with a small proportion of sulphuric acid, and the acid diluted with a quantity of water, a considerable proportion of coagulated albuminous matter is separated, and the oil floats above in a much purer state. It has been proposed to purify oils by filtration through charcoal. Other modes of purification have been proposed by Mr. Dossie. (Philosph. Magaz. vol. 15, and Trans. Soc. Arts, vol. 20.)

Oil boils at about 640°, and is decomposed. When dis-

tilled through red-hot fragments of brick, it is converted into a colourless volatile limpid oil, which has an unpleasant smell, is very inflammable, and boils at 180°. This is called Dippel's animal oil.

Train oil examined by Dr. Thomson produced:

Carbon . 6887		12 atoms
Hydrogen . 1610	which he distributes into	17 atoms
Oxygen . 1503		2 atoms

Spermaceti oil examined by Dr. Ure produced:

Carbon . 7891		10 atoms
Hydrogen . 1097	which he distributes into	8 atoms
Oxygen . 1012		1 atom

Spermaceti is a peculiar crystalline hard fatty matter, which is well known. It melts at 112°, and crystallizes on cooling. It is insoluble in water, dissolves in 150 parts of hot alkohol, is soluble in ether, and affords soap by management with alkalies, and is partially altered during the combination, and converted into a substance called by its discoverer cetic acid; he considers it to be an impure margaric acid.

Adipocire is an artificial fatty substance, produced by exposing muscle, or lean flesh, to the action of a running stream for three or four months, or to the action of strong nitric acid.

It is about as hard as tallow, of a crystalline texture, of a light yellow or greyish colour, and melts at from 96° to 126°. It is soluble in hot alkohol, from which it falls down as it cools, nearly white, having left its colour in the alkohol. It forms soap with alkalies. In burning, it diffuses an unpleasant odour.

By mixing together 1 volume of carbonic acid, 10 volumes of carburetted hydrogen, and 20 of hydrogen, and passing the mixture through a red-hot porcelain tube, M. Berard obtained a substance in small white crystals which was soluble in alkohol, lighter than water, and melted into a fluid resembling oil.

These five substances, when separated by art, have, generally speaking, properties sufficiently peculiar and distinctive; at the same time, the four first named are analogous to each other in many properties. But upon looking further into various kinds of animal matters, we find most of them occur extensively varied and modified, frequently intruding upon each other in their properties. Mucus sometimes appears a modification of gelatine, sometimes as if it were albumen softened.

In the blood albumen and fibrine are readily distinguished. The fibrine of the blood differs much in physical properties from flesh or muscle, although chemists have agreed to call it fibrine. In many cases there does not appear to be any well marked distinction between fibrine and coagulated albumen. Gelatine, on the other hand, is very abundant in all parts of young subjects, and has very distinct properties: in old quadrupeds, it is found in particular parts only; as age advances it becomes firmer, and appears gradually to approach to albumen.

Article 6. Blood.

The blood of some animals is colourless, but in quadrupeds and birds, the animals with the blood of which we are best acquainted, it is of a red colour. When fresh drawn, it appears to be an homogeneous fluid; but when examined with a common microscope, as it passes through the ramifying vessels, of a partly diaphanous body, as the web of a frog's foot, small red particles or globules are distinctly seen floating along in a transparent fluid.

A few minutes after the blood is drawn, it begins to coagulate into a jelly. Shortly after it is coagulated, a liquid begins to ooze from the whole surface of the coagulum. The coagulum gradually contracts as the liquid escapes.

until at last it becomes a red clot floating in a transparent liquid.

The liquid or serum consists chiefly of albumen, and may be coagulated by applying a temperature of 160°. From this coagulum a small quantity of mucus like fluid may be pressed out: it contains the saline matter that was in the blood, and which consists chiefly of muriate of soda, a small portion of subcarbonate of soda, a little muriate of potassa, traces of sulphate of potassa, phosphate of lime, of iron, and of manganese.

When the fibrine is separated previous to coagulation, as before pointed out, the red part of the blood falls down in the serum, which may be partially decanted off from it. When the serum is removed as far as is practicable, the red part is soluble in water, but partly falls down on standing. This part appears to be a distinct proximate principle, but difficulties occur in its analysis, which seem to have baffled the most able chemists. It contains a larger proportion of iron than has been detected in the other parts. While mixed in the blood, it gives it the property of becoming of a florid colour, on exposure to atmospheric air, or to oxygen gas.

A great deal of attention and labour, and even of imagination, has been bestowed to explain the cause of the red colour of this part of the blood. It appears that it has not yet been obtained in sufficient purity to be distinctly examined, and its other peculiar properties pointed out, as well as its colour.

The red part of the blood is not soluble in the serum it floats in. It appears in a microscope to be in small distinct globules, which are diaphanous at the edges. A common observer would think them to be small particles of a consistent, highly coloured, semi-transparent fluid, floating in a colourless transparent fluid, in which they are not soluble. Microscopists, however, think them to be little organized bodies, consisting of one vesicle cased in another, and of

different shapes in different animals. Many years have not elapsed since philosophers, in searching some of the animal secretions for the origin of vitality, as readily found little tadpoles swimming about in thousands.

Microscopes of high refracting powers produce, like fogs, indistinct appearances, and the imagination helps the judgment to settle its doubts.

Article 7. Muscle.

The appearance of flesh is well known. When it is macerated in three or four successive portions of cold water, it begins to whiten. If these waters are mixed and evaporated, a portion of albumen will coagulate, and may be separated. When the filtered liquor has evaporated by a very gentle heat to the consistence of a syrup, the greater part of it will be dissolved by alkohol, while the salts are left untouched in a little gelatine and water.

Upon evaporating the alkohol, a yellowish brown substance is obtained, which has the smell and taste of broth, which is soluble in water and in alkohol, and does not gelatinize. This substance M. Thenard calls osmazome.

The washed muscle, when analyzed by MM. Thouvenel and Fourcroy, produced chiefly fibrine, some albumen, gelatine, and a portion of the phosphates of soda, ammonia, and lime, and carbonate of lime. The aggregate proportion of salts appears to be about five parts to one hundred of pure dry beef muscle.

Mr. Berthollet boiled beef muscle in repeated waters until it gave out no more albumen nor gelatine. He then suspended it in a cylinder confined over water. The oxygen was converted into carbonic acid, the muscle became putrid, and on being boiled again, gave out gelatine.

The muscles of different animals differ much in chemical properties, as well as in appearance. They have a peculiar

structure, and differ in their other sensible properties from the fibrine of blood, while they nearly agree with it in chemical composition. Both appear to contain a less proportion of oxygen, and more nitrogen, than is contained in pure albumen.

Article 8. Skin.

The skin of animals is double, or consists of two very different parts.

The Cuticle, epidermis, or outer skin, is thin, unorganized, and insensible. It is this skin which is separated by blisters. After death it may be separated by immersion in hot water, or by putrefaction. It is insoluble in water and alkohol, soluble in pure alkalies and by the action of lime.

Dr. John found it resolve into indurated albumen 94 parts, mucus 5 parts, neutral salts 1 part.

The Cutis of animals is a dense vascular membrane, consisting of fibres interlacing each other. After being washed, macerated, and pressed, to remove the blood, it is not further acted on by cold water. It is dissolved by pure alkalies. It is converted into a fatty matter by a stream of running water, or by nitric acid. When long kept in cold water, it begins to putrefy, swells, and becomes spongy and softer.

By long boiling in water it is, in greater or less proportion, converted into a jelly or glue. Soft skins require less boiling to obtain glue, and the glue never becomes very firm. The stouter and harder the skins are, the more boiling they require, and the firmer the glue obtained becomes. The cutis is considered in consequence to be gelatine, so modified with albumen as to render it of very difficult solubility in water.

It is of the cutis that leather is made. The hides are

first cleansed from the cutis and hair, by soaking them in lime-water, scraping, and washing them.

The soft skins are then soaked for a time in water in which pigions' dung is mixed, and from thence are introduced first into a weak tan-pit, then into successively stronger pits.

The hard sole leather skins are introduced for a short time into a strong tan-pit: then they are immersed in a very diluted sulphuric acid; after which they are immersed at once into strong tan-pits, and kept there several months, bark being added from time to time. During this process the tannin penetrates the texture, combines with the gelatine and albumen, and forms the insoluble compound leather.

Article 9. Membranes, Tendons, Ligaments.

Membranes are of three sorts, the serous, the mucous, and the fibrous, they appear to be formed of albumen, and different proportions of gelatine.

The mucous membranes are of the most tender structure; and by boiling produce a large proportion of gelatine. The serous membranes are of firmer structure, and appear to contain a larger proportion of hardened albumen. The fibrous membranes are the firmest in structure, and many of them approach to tendons, both in structure and use.

Tendons and ligaments are very similar to each other in structure. They appear to be gradations of similar compounds with fibrous membrane. Tendons give out a large proportion of gelatine in young subjects. Ligaments give out gelatine more sparingly. The changes produced upon these bodies by the long continued action of hot water, strongly favours, to a certain extent, the opinion of M. Berzelius; that certain of these bodies are converted into gelatine during the operation of boiling.

Fibrous membrane and ligament in drying become horny, and lose from half to three-fourths of their weight.

Cartilages are of different kinds. They appear to consist of an albuminous substance for the most part. They generally contain a minute proportion of earth. In drying they lose from two-thirds to three-fourths or more of their weight.

Article 10. Bone.

The bones of animals vary much in hardness or closeness of texture. The bones of young animals are less firm and solid than those of older animals of the same species.

They are composed of a soft animal substance, which is organized and vascular; in which is deposited a large proportion of earthy matter, to which they owe their solidity.

When a bone is exposed to a red heat, for a sufficient time, the whole of the soft animal substance is decomposed and evaporated; the earthy and saline matter remains, retaining the exact form, and apparent structure of the original bone.

The animal substance may be obtained by macerating the bone in diluted muriatic acid. It will, at length, dissolve the earthy matter, and leave the animal substance, in appearance, similar to a soft, flexible, and porous cartilage. When dried and immersed in oil of turpentine it becomes diaphanous.

When bone of a young animal is broken into small pieces and boiled, a quantity of gelatine may be obtained. This quantity is greater in proportion as the bones are of lighter texture, and as the animal is younger.

Porous bones, and the hollow parts of cylindrical bones, contain also a variable quantity of animal fat or marrow.

The bones of different animals vary in their compositions, and the proportion of their earthy ingredients.

They vary also according to the age of the animal, and the density of the bone.

In an analysis of ox-bone M. Vauquelin obtained animal matter 51, phosphate of lime 37.7, carbonate of lime 10., phosphate of magnesia 1.3; = 100.

The following are the results of the analyses of M. Berzelius of several varieties of bone.

	Dry Human Bone.	Enamel of Human Teeth.	Dry Ox-bone.	Enamel of ox Teeth.
Cartilage	32.17		30.30	3.56
Blood-vessels . . .	1.13			
Phosphate of Lime .	51.04	85.3	55.45	81.
Carbonate of Lime .	11.3	8.	3.85	7.1
Phosphate of Magnesia	1.16	1.5	2.05	3.
Soda and Muriate of Soda, &c. . . .	1.20	2.	2.45	1.34
Fluate of Lime . . .	2.	3.2	2.90	4.

The teeth of animals are much more dense and hard than the other bones, and consequently contain a smaller proportion of animal matter.

The shells of eggs consist chiefly of carbonate of lime, with a small proportion of the phosphate; carbonate of magnesia, iron, and sulphur, have been detected. They are united to a small proportion of membraneous animal matter.

The shells of crustaceous animals, as lobsters, crawfish, crabs, &c. are composed chiefly of carbonate of lime, with a portion of phosphate, and membrane.

The hard porcelaneous marine shells, including the land snails, are composed of the same ingredients cemented in part by a minute portion of animal matter.

Mother-of-pearl shells, as the oyster, and the pearl itself, are composed of carbonate of lime and animal membrane, partly disposed in alternate layers. Mother-of-pearl consists of nearly one part by weight of membrane to three of carbonate of lime.

There is an extensive class of curious little animals, called by naturalists zoophytes. Some of them have the power of building for themselves, from their own secretions, according to certain laws, domiciles of carbonate of lime, which are variously formed, and attached together. Thus are produced the various corals and corallines; some of which are hard and stony almost, others soft and very flexible. These substances, according to the analysis of Mr. Hatchett, and of various other chemists since, consist of a more or less firm and dense albuminous-like membrane, with carbonate lime in various proportions, and generally a small proportion of phosphate.

Article 11. Brain.

The brains of animals have a strong general resemblance, both in organization and in substance. They consist of two parts, called, from their colour, cineritious and medullary; but their substances are similar. When quite fresh, the texture has no distinct fibres, except in certain parts. It is close, soft, and rather elastic. It soon loses its firmness and elasticity; and on exposure to air, runs rapidly into putrefaction, when it emits a most disgusting odour.

Cold water does not act upon it, but it may be rubbed into an emulsion with water. On applying heat to this emulsion, a quantity of white coagula are produced, which are insoluble in water or alkohol.

M. Vauquelin, in an analysis of the brain, obtained:

Water	80. parts
White fatty matter	4.53
Red ditto	.7
Albumen	7.
Osmazome	1.12
Phosphorus	1.5
Sulphur and saline matter .	5.15

Article 12. Horn.

The horns of animals are of two kinds, in texture as well as in the manner of their growth.

The horns of the ox, the sheep, the goat, and of some other animals, are very well known as to their structure and hardness. They give out gelatine by long boiling, which dries again into a firm horny glue, and leaves an undissolved substance, which may be compared to a very firmly indurated albumen.

The horn of black cattle, according to the analysis of Dr. John, contain:

Indurated albumen	90 parts
Gelatine, albumen, and osmazome	8
Fat	1
Saline matter	1

The horns of the different varieties of deer are more like bone, both in structure and composition. The chief difference is, that they are tougher, and contain less earthy matter than is contained in bone.

The claws of animals, and the hoofs, the human nails, the shell of the tortoise, the scales of reptiles, the coverings of insects, and the feathers of birds, have a strong general resemblance. They grow by a sort of vegetation; they vary a little in hardness and toughness; they are considered as varieties of very firm coagulated albumen; but they might rather be considered as peculiar animal proximate principles analogous to albumen, but varying according to their peculiar applications. The coverings of insects are thought to approximate in some degree to vegetable lignin.

The scales of fish are composed, like pearl-shells, of membranous layers, with a small proportion of phosphate of lime, and, perhaps, of carbonate.

Article 13. On the Chyme, and Secretions concerned in its Formation.

There are several secretions which are prepared in animals for the purpose of assisting the conversion of the food into the chyle, the material which enters the blood-vessels for the support and nourishment of the animal.

The first of these that occurs to the attention is the saliva. It is secreted by six glands situated near the mouth. It is a weak solution of mucus in water, containing a minute portion of muriate of soda, carbonate of soda, and lactate of soda.

The next is the gastric fluid, secreted in man by small and almost invisible glands, dispersed in the thin substance of the stomach. Little is known of its chemical composition. It has the peculiar property of dissolving the food taken into the stomach, and converting it into a pulpy mass called chyme, preparatory to its further change.

As animals are ordained to live on animal or on vegetable food, so the chemical properties of the gastric fluid must vary. Observation accordingly shews, that the gastric fluid of a dog cannot digest raw mallow leaves and cabbage; nor the gastric fluid of a rabbit, raw meat and ligaments.

For the secretion of good gastric fluid, it is necessary that the stomach be in a healthy state. That its action is purely chemical, is evident from this fact, were there no other evidence: in men, and more particularly in children, who have died suddenly, being previously in sound health, the gastric fluid that is in the stomach acts equally upon the stomach, and upon its contents, dissolving them both.

Article 14. Bile and Picromel.

The bile is a peculiar thickish yellow liquor, which is

poured into the intestines at a short distance from the stomach. It is produced in considerable quantity. A bulky gland, and a peculiar circulation, both of which are very liable to accident or disease, are adapted for its production. It is produced in all vertebral animals also that have been examined, and yet its precise use is unknown. Physiologists have guessed at its use, and still do so, but guessing is not knowledge. Here is one of the many instances which ought to render philosophy humble. The gastric fluid, a necessary powerful chemical agent, without which life could not continue long, is secreted into the stomach by a few glands, which from their minuteness are almost invisible; whilst a large bulky dangerous apparatus is carried about by almost every animal, for the preparation of a fluid, the use of which is absolutely unknown.

It *appears* to be necessary in completing the process of digestion, and in assisting the conversion of the chyme, or product of digestion, into chyle.

The bile of different animals varies much, possibly to adapt it to the difference of the chyme produced in the stomach of different animals.

Fresh ox bile has a faint, rather peculiar, smell, is of a greenish yellow colour, and slightly reddens vegetable blues. Its taste is a nauseous maukish bitter; it varies a little in consistence, and is sometimes partially coagulated. It becomes putrid and offensive from keeping. It is soluble in water, in alkohol, and in alkaline solutions. It dissolves oils and fats, and in consequence is used by scourers instead of soap, as being less liable to injure animal and vegetable colours.

The human bile is sometimes of a greenish colour, sometimes of a brownish yellow. It is mostly taken for chemical examination from the gall bladder, where it is found somewhat thickened and altered in colour, and often mixed with coagula.

M. Berzelius found it to consist of water 908.4, picromel 80., albumen 3., soda 4.1, phosphate of lime .1, muriate of soda 3.4, phosphate of soda with a trace of lime 1; = 1000.

M. Thenard, in analyzing another portion of human bile, found the following products:

Water 700, picromel and resin 84.3, yellow matter 4.5, soda 4., phosphate of soda 2., muriate of soda 3.2, sulphate of soda 0.8, phosphate of lime 1.2, and a trace of oxide of iron; = 800.

Picromel is a substance named by M. Thenard, and is that proximate principle to which bile owes its distinguishing character.

To obtain it, add to the bile sulphuric acid diluted with four times its quantity of water; a yellow precipitate falls; separate it by decantation, and add fresh acid as long as any precipitate appears. When the whole is separated, and the mixture kept in a gentle heat for some hours, the green matter that remains is called resin of bile. According to Thenard, it is a compound of picromel and sulphuric acid, from which the acid may be separated by carbonate of baryta.

Picromel has a greenish colour, an intensely bitter taste, is soluble in water and alkohol, and would appear to be the pure bile separated from its saline and albuminous matter.

According to Dr. Thomson, it is composed of carbon 54.53, hydrogen 1.82, oxygen 43.65.

Article 15. On Chyle.

Chyle is a white opaque fluid, which is formed from the chyme as it passes out of the stomach, and it passes into the blood-vessels for the supply of matter for the growth, and the waste, produced by the various animal functions. It has been examined by MM. Vauquelin, Brande, Berzelius, and other chemists.

It has a slightly blueish milky colour. Its specific gra-

vity is less than that of blood. In the course of a few minutes after removal from the lacteal vessels, it coagulates, and after a time gradually separates, as the blood does, into a coagulum, and a transparent fluid.

The coagulum resembles curd in appearance, and gives out fatty and an albuminous matter when treated with acids. It is soluble in the alkalies.

The transparent fluid, when heated, produces albuminous flakes. When the strained liquid is evaporated, it deposits crystals having a resemblance to the sugar of milk. The chyles of different animals appear to vary in some degree.

Article 16. On Milk.

Milk, its use, and that it varies somewhat in different animals, are facts well known.

All milk, after standing, produces a cream, but varying both in quantity and richness. When the cream is agitated by churning, it separates into butter curd and whey. Cream, the specific gravity of which was 1.0244, when analyzed by M. Berzelius, produced butter 4.5, curd 3.5, whey 92; = 100.

When an acid is added to milk, or a portion of gastric fluid, or of the inner coat of an animal's stomach, which is supposed to act in consequence of the gastric fluid contained within its substance, it becomes coagulated, and separated into curds and whey. Rennet, which is usually employed for the coagulation of milk, is the inner coat of the stomach of a calf.

Curd is very similar in properties to coagulated albumen, and may be considered as a variety of it, so constituted as not to be coagulable by heat. Curd is very brittle, insoluble in water and alkohol, and soluble in alkalies. When pressed dry, and kept for a time, it is gradually converted into cheese. If the curd be very pure, the cheese becomes

hard, horny, and tasteless almost. If it contains a quantity of the butter intermixed in its substance, it becomes brittle, and more flavoured. The ashes of curd yield a large proportion of earthy phosphates.

M. Proust, by a circuitous process, obtained from curd a small quantity of two substances, called caseic acid, and caseic oxide. Combined with ammonia, they assist in forming and giving flavour to cheese.

The whey, after being separated from curd, still contains a portion of butter and of curd. When they are separated by boiling, and then cooling and filtering, upon the whey being slowly separated, it yields a quantity of sugar of milk, and successively the other ingredients of the milk.

Cow's milk, when separated from the cream, afforded to M. Berzelius, water 928.75, curd with a trace of butter, 28., sugar of milk 35., muriate of potash 1.70, lactic acid, lactate of potass, and a trace of iron, 6., earthy phosphates .3; = 999.75.

Sugar of Milk. To obtain this substance pure; when whey has been evaporated to the consistence of honey, dissolve it in water, clarify with white of egg, and again evaporate until it grow syrupy: on cooling, the sugar of milk will separate in white brilliant crystals. It has a sweet taste; is soluble in four parts of boiling water, and seven of cold. It is insoluble in alkohol. It melts and burns like common cane sugar.

By analysis it produced carbon 38.825, oxygen 53.834, hydrogen 7.341; = 100.

When sugar of milk is heated with nitric acid, and left to crystallize, oxalic acid is produced; but when the solution is directly diluted with water, a white precipitate falls down. This precipitate is *saccholactic* or *mucic acid.*

When milk or whey has become sour it produces a peculiar acid. To obtain it pure evaporate sour whey to one-eighth.

Filter and precipitate lactate of lime with lime-water, and separate the lime by oxalic acid. Dissolve this impure lactic acid in alkohol, filter and distil off the alkohol. The lactic acid is an uncrystallizable, deliquescent, yellowish-brown fluid, differing in some of its properties from acetic acid, and evaporating with an acid smell. Its saline compounds do not generally crystallize, and are soluble in alkohol.

Women's milk is much poorer than cow's milk, containing less oil and curd. The cream is poor, the oil does not separate into butter, and it contains a larger proportion of its proper sugar.

Asses' milk strongly resembles women's milk. It gives less cream, and the cream affords a soft imperfect butter.

Goat's milk is in general richer than cow's milk, at least in the proportion of curd.

Milk, at least the milk of the mare, is susceptible of vinous fermentation. A vinous liquor is prepared from it by the tartars, from which alkohol may be obtained.

Article 17. Ear-wax and other Secretions.

Several other animal secretions are produced from the same ultimate elements. They have each of them peculiar properties adapted to their peculiar uses.

The wax of the ear is a tenacious yellowish bitter substance, which does not readily dry. It is miscible in water, and partly soluble in alkohol. It contains albuminous matter, a little oily matter, a bitter sort of resin, and some saline matter.

Synovia is a thick mucilaginous matter, secreted into the cavity of the joints to lessen friction. It is a viscid fluid, composed of a mixture of gelatine and uncoagulated albumen with water.

The lymph that is poured out upon the surfaces of serous

membranes, such as the cavities of the abdomen, of the thorax, and of the pericardium; and that also which is poured into the reticular membrane throughout the body, is similar to synovia, both in use and composition, but is much more fluid.

The humours, as they are called, of the eye, have the perfect transparency, and the various densities which are necessary for their respective functions; and are varied combinations of the same animal matters. The crystalline lens is chiefly hardened, dense, coagulable albumen: The tears, the secretions of the mucous membranes of the nose and lungs, are supplied with a small portion of animal mucus. All these fluids contain a certain proportion of saline matter.

Article 18. Urine.

§ 1. The urine is considered as an extrementitious body. It is, however, a peculiar secretion, and contains, among a great variety of bodies, certain animal proximate principles, which are not present in the blood, nor in any other fluid. In consequence of the changes this fluid undergoes during almost every general disease, and in consequence of the numerous diseases which the organs adapted to its secretion, and discharge are subject; it has occupied a great deal of attention from the chemist and physician, as well as from the physiologist. To treat of the subject fully would be incompatible with our limits.

The substances most usually found in urine are:

1. Water
2. Urea
3. Gelatine and Mucus
4. Albumen
5. Phosphoric Acid
6. Uric and Rosacic Acid
7. Fluoric Acid
8. Benzoic Acid
9. Lactic Acid
10. Sulphuric Acid
11. Muriatic Acid
12. Sulphu

13. Ammonia
14. Potassa
15. Lime
16. Magnesia
17. Silica.

These bodies are variously combined according to the balance of their respective attractions.

Several of these substances are always present in the urine of a healthy person; some of them are not always detected. They exist too in different proportions in different animals, and in the same animal also at different times.

The urine of graminiverous animals is generally free from uric acid, has generally less urea; on the other hand, benzoic acid is more generally present; and carbonic acid, both free and in combination.

The urine of animals, feeding on flesh, generally affords uric acid, and a larger proportion of urea; and, while fresh, is free from carbonic acid.

Generally speaking, healthy human urine is transparent, of a pale brownish yellow colour; at first of a rather agreeable flavour, and reddens blue paper. After a short time, the peculiar smell called urinous is perceptible. On standing a few days, it first becomes sour and peculiar, then putrid, and peculiarly offensive.

The numerous analyses of urine by different chemists, as might be expected, do not exactly agree. A specimen analyzed by M. Berzelius, one of the most able and recent labourers on this subject, produced:

Water	993.
Urea	30.10
Sulphate of potassa	3.71
Sulphate of soda	3.16
Phosphate of soda	2.94
Muriate of soda	4.45
Phosphate of ammonia	1.65
Muriate of ammonia	1.50

Laetic acid, lactate of ammonia, animal matter insoluble in alkohol, and inseparable urea	17.14
Earthy phosphates with a trace of lime	1.
Uric acid	1.
Mucus	0.32
Silica	0.03
	1000.

§ 2. Urea, or nephrine, is a proximate principle, peculiar to urine, and communicates to it its chief and peculiar distinctive properties. To obtain it pure, evaporate fresh urine to a syrupy consistence; pour upon it four times its weight of alkohol, in repeated portions; apply a gentle heat: distil slowly to the consistence of a syrup, and set it aside to crystallize. It may be further purified by a circuitous process, pointed out by Dr. Prout.

When pure, it crystallizes in colourless plates crossing each other, or in prisms. It has little smell, but a strong acrid taste. It is deliquescent, and extremely soluble. It dissolves in alkohol, and crystallizes from it more completely than from water. It fuses in a strong heat, sublimes partly, and is partly decomposed.

It combines with nitric acid and with oxalic acid, forming compounds which are capable of crystallizing.

A solution of urea in water decomposes spontaneously, becoming putrid and offensive. If gelatine or other animal matter be present, the change is more rapid, and the odour more offensive. When boiled in water for a length of time, it is wholly decomposed into ammonia and acetic acid; both of which escape in vapour. When treated with alkalies, it is decomposed, and ammonia produced.

It contains in its composition a larger proportion of nitro-

gen than any other animal compound, and its tendency to decomposition is greater.

According to a very laboured analysis of Dr. Prout, it is constituted of:

Carbon	20.	1 atom
Hydrogen	6.66	2 atoms
Oxygen	26.66	1 atom
Nitrogen	46.66	1 atom

§ 3. Uric acid is another compound almost peculiar to urine, but occasionally found in the gouty concretions called chalk-stones.

When the urine is evaporated to half its volume, uric acid separates, or rather urate of ammonia, in conjunction with phosphate of lime. Muriatic acid dissolves the latter, leaving the urate of ammonia in the state of a reddish powder. It may be dissolved in pure potassa, and the uric acid precipitated by muriatic acid in excess.

Pure uric acid has neither taste nor smell, and is almost insoluble in water, alkohol, or ether. According to Dr. Prout, it requires 10,000 parts of water for its solution; according to Fourcroy, in 2000; according to Dr. Henry, in about 1400. It is in white shining plates, which redden wet litmus paper. It is insoluble in muriatic acid, and in sulphuric, unless it be concentrated. It is soluble in nitric acid, even when diluted. When heat is applied to this solution, a reddish vapour escapes with effervescence. The solution becomes of a deep red colour, and stains the skin of a bright red, which becomes purple on exposure to the sun; when evaporated to dryness, a pink sediment is left.

This acid dissolves in solution of pure potassa, soda, and ammonia, but not in the carbonates, combining with the alkalies, and other bases, into salts which are of difficult solubility. Urate of ammonia is frequently present in urinary calculi; urate of soda in gouty chalk-stones. Urate

of ammonia is of a wood or fawn colour, and soluble in 480 parts of water. It is more soluble in pure potassa or soda.

§ 4. When uric or lithic acid is dissolved in diluted nitric acid, and the excess of nitric acid neutralized with ammonia, as the slowly evaporating solution becomes concentrated and of a deep purple colour, beautiful, dark, garnet-red crystals begin to separate in considerable quantity. These crystals are composed of an acid called purpuric, combined with ammonia. To obtain the pure acid, these crystals are to be digested with caustic potassa until discoloured, and precipitated by dropping into the solution dilute sulphuric acid, when it appears in the state of a pearly cream-coloured powder, which is very insoluble.

Purpurate of ammonia is soluble in 1500 parts of water at 60° into a rose-red sweetish solution.

According to Dr. Prout, who first pointed out this acid, all its saline compounds have the characteristic red colour.

§ 5. There is also sometimes met with in urine a substance called rosacic acid by Dr. Prout, who pointed it out as a powder of a lively red colour, which is very soluble, reddens litmus, and forms soluble salts.

A reddish or brick-coloured sediment frequently falls down, sometimes in crystals, in certain stages of fever, of the gout, and in many other cases. Dr. Prout considers this as consisting partly of purpurate of ammonia, produced by the action of nitric acid on the uric, within the urinary organs, and partly of the peculiar acid, which he denominates the rosacic, from its resemblance to the rose in colour.

MM. Vauquelin and Vogel adopt an opinion not dissimilar. This acid differs from the uric by being soluble in hot water, and having little tendency to crystallize. It precipitates muriate of gold of a violet colour. Concentrated sulphuric acid converts it into a substance of a deep red

colour, and afterwards into a white insoluble substance, having the properties of uric acid.

It is soluble in alkohol, and by this property it may be separated from the purpurate of ammonia and soda.

The small hard crystals which are sometimes deposited from the urine, and are called gravel, are urate of ammonia, sometimes mixed with urate of soda, and with this acid.

§ 6. In what manner the vital agency acts in the production of the various secretions, is wholly unknown. It would appear that it affects the natural chemical attractions, giving them a new tendency, which is directed, by the peculiar structure of different glands, to the production of the peculiar compounds adapted to the respective final causes.

A proportionally large quantity of blood passes to the kidneys, and the quantity of the secretion is very large. The greater part of the water and extraneous matter that gets into the circulation escapes again through them, and, in consequence, variously affects the composition of the urine. How readily it is affected by substances passing into the stomach, may be judged of from observing that many vegetable compounds, which it might be expected would be decomposed in the stomach, shew their effect in the kidneys and bladder. This is the case with most resinous substances, with the stimulus of cantharides also, and with many vegetable colouring bodies. Some bodies appear to suffer peculiar changes in their passage to the kidneys. When oil of turpentine is taken, the urine acquires a violet smell. The effect of peas, asparagus, and cabbage, is well known But although the kidneys are a secreting, and not merely an excreting, organ, yet the vital agency exerts but a weak influence over them. The urine is, in consequence, varied from every slight cause, and still more so from disease, and has in all cases a strong tendency to decomposition.

It has been noticed by Mr. Rose and Dr. Henry, that in some cases of chronic hepatites no urea is produced. In diabetes it is wholly absent, and sugar is produced in its place. In some diseases, the albuminous part of the blood has been secreted in great abundance, and even red blood has passed, apparently by secretion. In some cases, unexpected compounds, such as nitric and oxalic acids, and silica are found.

Article 19. Urinary Calculi.

We have seen that some of the bodies which are met with in the urine require a large quantity of water for their solution. It is not wonderful, then, that they should sometimes be precipitated in some of the urinary passages. The tendency to this deposition is so strong, that in some persons it is perpetually taking place; and often when a nucleus is offered, the precipitated particles adhere to it, and gradually accumulating, produce what is called a stone or calculus.

Most calculi are formed upon a nucleus. Sometimes this nucleus is a clot of blood, or of coagulated albumen; sometimes some extraneous matter which has slipped into the bladder, a bit of bougie for instance, and often a few particles of crystallized uric acid, or urate of ammonia, that have agglutinated together. These concretions are composed of one or other of the more insoluble bodies that are present in the urine. The bodies mostly occurring are urate of ammonia, uric acid, phosphate of lime, phosphate of magnesia and ammonia, sometimes oxalate of lime, and more rarely silica, carbonate of lime, and a compound named by Dr. Wollaston cystic oxide. Sometimes two or more of these bodies are present in the same concretion, when they are more generally united in layers. At times,

a calculus composed of one body is covered and enlarged by another. They are of all sizes, from that of a pea upwards; sometimes, although rarely, they weigh six or eight ounces, and by chance they have been met with weighing twenty ounces or more.

Article 20. Other Concretions.

In the gall-bladder hardened concretions are sometimes met with. They are mostly small, but have been met with weighing an ounce or more. They consist generally of a hard, fatty, lamellated substance, of a greasy feel on the cut surface, that has been named cholesterine. They are generally of a light colour; and sometimes dark coloured, from being combined with altered bile.

When this cholesterine is treated with nitric acid, in the manner pointed out by M. Pelletier, it is dissolved and converted into a substance called cholesteric acid, which is nearly insoluble in water, but soluble in alkohol, from which it crystallizes in needles by spontaneous evaporation. It is soluble in ether also, and volatile oils. It slightly reddens litmus, and combines in definite proportions with alkaline bases.

Concretions sometimes occur in various other parts of animals, but are rather objects of medical treatment than of chemical attention.

Many particular genera, and even species of animals, produce secretions, having peculiar properties; such as the different poisons of serpents and insects, silk, the web of the various spiders, ambergris, musk, civet, &c. but they are too numerous to be considered here.

Part 3. *Putrefaction and its Productions.*

It has been already observed, that the various kinds of fermentation are merely the natural decompositions of certain proximate vegetable or animal principles; but which may be guided by art to certain purposes.

As soon as the vitality which has produced organic compounds has ceased, the natural chemical agencies of the elements that composed them come into action. There is consequently a strong tendency to decomposition. But for chemical action to take place, it has been shewn that certain facilities are requisite. The chief of these are a temperature between about 50° and 100°, and a certain proportion of water. Other bodies when present, atmospheric air in particular, modify and vary the process, but are not necessary to it. For instance, when an animal body is frozen, no change takes place in its structure or composition until its frozen state is removed.

A curious instance of this lately occurred in Siberia. The immense animal, called the Siberian mammoth, the bones of which are now preserved in the museum at Petersburg, was first discovered in a perfect state, but frozen in a mass of ice, in which it must have been enclosed during many ages; since neither history nor tradition give any trace of a similar race of animals. During several years after it was discovered the crust of ice was observed to be slowly wasting; the hair and flesh continuing in a perfect state; and when at length the government sent persons to examine it more minutely, the crust of ice had nearly disappeared, and the greater part of the flesh had been eaten by dogs; the bony parts and the hair only remaining.

When, on the other hand, animal or vegetable matter is

hastily dried, the dry matter suffers no further perceptible change; except that it may be slowly acted upon by the varying temperature, or by the hygrometric moisture of the air.

The different parts of vegetable or animal bodies are more or less exposed to this natural decomposition, according to their texture and composition. Solid wood and bone, for instance, resist this tendency for a great length of time; while the softer or fleshy parts obey it immediately, and by their rapid decomposition produce the phenomena of putrefaction.

When a quantity of dead soft and moist vegetable matter is thrown together in the open air, in a warm temperature, the texture, colour, and distinctive properties almost immediately begin to give way; caloric is evolved, the vinous and acetous periods of fermentation are rapidly passed over, and the mass speedily runs into putrefaction. During this time, the different parts of the mass are successively becoming disintegrated, and dissolved into their ultimate elements. But these do not at once escape; they react upon each other at the moment of evolution, producing more simple compounds, which vary somewhat according to their proportion, their number, and other complicated circumstances. The combinations, however, are generally binary. Those which assume the gaseous form escape; others remain in the mass, and are subject to further changes, until at length they escape in their turn.

So that all the gaseous offensive matters escaping during putrefaction of vegetables, are merely the same elements, more simply combined with each other, and with the elements of the water and of the atmosphere.

As the composition of the vegetable matter varies therefore, so must the products of its putrefaction vary. The most usual gasses that escape are hydrogen, carburetted

hydrogen, sulphuretted hydrogen, carbonic oxide, carbonic acid, sometimes phosphuretted hydrogen, and various other compound gasses. These generally carry with them a small proportion of the solid decomposing matter, and this, added to the gasses, increases the disgusting odour.

When a mass of animal matter is thrown together in a similar manner, similar decompositions and new combinations take place, but with greater complication and rapidity. Animal compounds are more complete than vegetable, and less permanent. Nitrogen, which, in vegetables, is an occasional element only, in animals is present in very large proportion, and performs a very important part in the putrefaction, as well as in the growth of animal matter. Phosphorus and sulphur are present in more abundance, particularly the former. The consequence is, that larger proportions of phosphuretted and sulphuretted hydrogen are produced, and a very large proportion of ammonia. This alkali is not in itself disagreeable, but it seems to communicate its volatility and pungency to other of the decomposing bodies; and altogether they produce the detestable odours so well known as the production of putrefying animal matter.

Putrefying animal matter acts as a ferment when added to fresh matter, and hurries on its decomposition, just as yeast hurries on the vinous fermentation.

It appears highly probable that, by this assimilating property, it acts in producing contagious fevers. Putrefaction does not, and cannot, take place in either the solids or fluids of the living body; but the reaction of the vital agency in resisting it, seems to produce fever; and, during its existence, all the secreted fluids seem to be imbued with a ferment which carries them into a rapid putrefaction.

Physicians have theorized on this subject in various ways, and will continue to do so; but the facts are perma-

nent. They point out the necessary precaution, in every case where fever prevails, not merely of common cleanliness, but of attentively removing immediately every excretion that can, by possibility, serve as a ferment; for they gain strength by keeping. Many secretions which are sweet, and probably harmless, at the moment of their formation, become very offensive, and apparently highly contagious, in a few hours. The rapidity with which putrefaction takes place after death, in some cases, is astonishing.

When the temperature is low, at 40° for instance, and the quantity of moisture comparatively small, these changes are retarded merely; but if the atmospheric air be, at the same time, excluded, they produce a result which differs considerably: the ammonia, instead of escaping, combines with the animal matter, which, in the mean time, becomes converted into adipocire, thus producing an imperfect fat soap.

Before the year 1786, the principal burying-ground of Paris was become so offensive and dangerous, in consequence of the enormous quantity of decayed and decaying animal matter, as to call for a remedy. The practice there had been to dig a large and deep pit, in which they successively placed the dead bodies, covered with a few inches only of earth, until the pit was filled. In the succession of time, the whole of the burial-ground was thus filled.

Upon removing this mass of matter, it was discovered that the greater part of the soft parts were converted into an unorganized mass of fat soapy matter, of a peculiar smell, and whitish colour. When analyzed by M. Fourcroy, it proved to be the peculiar fatty matter already spoken of, under the name of adipocire, combined with ammonia and water.

The putrefaction of animal bodies may be retarded or

prevented by various means. A freezing temperature has already been noticed, and also the abstraction of moisture. The application of salt for the same purpose is well known. It is prevented also by immersing animal matter in alkohol, or a strong solution of alum, and of some other saline bodies.

Embalming is a practice for the same purpose. The Egyptian mummies offer an instance both of its success and antiquity. In this process, all parts of the body are, as far as is practicable, deprived of their water and moisture, and then impregnated and stuffed with aromatic substances, the best of which would be resinous substances, essential oils, camphor, and bitumens. After which they are rolled in waxed cloth. Charcoal, particularly fresh animal charcoal, where its colour does not prevent its application, is one of the most efficient substances that can be used for this purpose.

THE END.

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